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INDIARUBBER AND GUTTA PERCHA

INDIARUBBER AND GUTTA PERCHA

A Complete Practical Treatise

ON

INDIARUBBER AND GUTTA PERCHA

IN THEIR

HISTORICAL, BOTANICAL, ARBORICULTURAL
MECHANICAL, CHEMICAL, AND
ELECTRICAL ASPECTS

TRANSLATED FROM THE FRENCH

OF

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BY

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LATE LECTURER ON THE CHEMICAL TECHNOLOGY OF GUMS, RESINS, ETC. ETC.
THE POLYTECHNIC, REGENT STREET

WITH 145 ILLUSTRATIONS AND 125 TABLES

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AUTHORS' PREFACE

If the reader will be good enough to take a rapid glance at the bibliographical résumé at the end of this treatise,[1] *he will very readily acknowledge that the special literature devoted to indiarubber and gutta percha is considerable, not only in foreign countries, but also in our own, and that such is the case although only a comparatively short time has elapsed since the discovery of these raw materials and their industrial applications.*

If we to-day, therefore, undertake the responsibility of presenting to the public a new treatise, dealing with the same subject, it is not for the mere sake of the vainglory of adding another unit to the already considerable number of works and memoirs published, as many on "gum elastic" as on "gum plastic." We have a higher ambition, a less futile object. We acknowledge that almost all the treatises hitherto published have the great merit of having dealt excellently with the subject from the special point of view or vantage ground in which the authors were placed, but, taken as a whole, they are, nearly always, awanting in that cohesion and in that unity of purpose which the reader looks for in a work of this nature. They are deficient in that co-ordination which is so essential for those who seek to embrace, in a single glance of the eye, the results obtained, up to a certain moment, on any given subject. The greater number of treatises which, to our own knowledge, have been edited with this end in view, contain, most generally, obsolete information, and no longer respond to the wants of the present time. Like man, books get old quickly nowadays, and a book is scarcely written before it requires modification, nay even completion.

Freely availing ourselves of the elements of an abundant special literature, and profiting by our own personal experience, we have been able to effect our purpose, to combine in one harmonious whole the precious scattered elements of an infinite number of publications, to extract from them their quintessence, and make of them an exact précis or résumé responding to the needs of the present day. In this way we have been enabled to methodically classify in their turn or rotation the plants producing the raw material, the commercial varieties most commonly met with on the international market, with the characteristic signs of their individuality, and have also been enabled to assign to them a certain habitat in each part of the globe. Moreover, thanks to these elements, we have been enabled to deal competently with the rational culture and acclimatisation of indiarubber and gutta percha plants, and to devote ourselves to a critical study of the methods employed, not only for the collection of the latex, but also for the extraction therefrom of the respective rubbers and gutta perchas, and thus have been enabled to recommend the method which appeared to us the most advantageous for each species.

[1] *Omitted from Second English Edition.*

After having studied the physical properties of the rubbers in their natural state, as well as the mechanical transformations which are necessary to impart to the crude material the qualities which industry demands of it, this question has led us to examine such a singularly interesting phenomenon as the vulcanisation of indiarubber, and we have endeavoured to define this transformation in as plain and intelligible a manner as possible. Our theory may be criticised, but contradiction throws light on the subject, and we shall be pleased if, in giving rise to discussion, we have been enabled to shed some light upon a question which is still so obscure.

We have next studied the chemical and physical properties of indiarubber after it has been essentially transformed by vulcanisation, to again occupy ourselves with the reclamation of the waste, and finally to dwell a moment on extreme vulcanisation, that is to say, on the preparation of hardened rubber, namely, ebonite.

We have assimilated all the data at our disposal on the methods of analysing rubbers, and examined the methods of technical testing and valuation proposed by several technological savants; then we have been induced to take up the substitutes and artificial products capable of replacing the crude material to a certain extent, whether they act by correcting certain faults in the latter, or whether it be proposed by means of them to lessen the cost.

In regard to gutta percha we have followed the same method of study, not without taking into account the difficulties incidental to such an undertaking. The botanical origin of gum plastic, as well as its commercial varieties, presents to any one who wishes to obtain information in regard thereto a regular muddle or maze. To face this labyrinth is to incur the risk of getting lost in it. If, thanks to more recent researches, the darkness tends to be dissipated, complete light is nevertheless far from being an accomplished fact, and we shall be pleased if, on our part, we have contributed a little to advance such a difficult and complex question.

However that may be, we do not forget that our work is, in a large measure, the result of the labours of our predecessors. We have often, in fact, been limited to assimilating the fruits of their learned and patient researches. We have not always and in every instance quoted the sources from which we have drawn our information, so as not to hinder the progress of our work. We beg the specialists, who have been good enough to lend their often precious assistance, to receive here the legitimate homage of our sincerest gratitude.

If the reader obtains from our treatise information of use to him, we shall be amply recompensed for our efforts and our trouble, for our motto is and always shall be—

To be Useful.

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INDIARUBBER

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HISTORICAL INTRODUCTION

It would be superfluous to describe, in detail, the successive phases of the discovery of the industrial properties of that peculiar body, called Indiarubber. Others have already done so, and with a masterly hand. But to avoid all mention of these phases would be to forfeit the pleasure of doing homage to the powers of observation, and the inventive genius, of the men who founded a great industry with a substance which, at the outset, appeared to be, from a technological point of view, of very trivial value indeed. So far back as 1868, Turgan, in his book on the *Great French Factories* (*les Grandes Usines de la France*), was, even then, able to say: "Indiarubber has, at the present day, become not only an essential factor of industry, but also, and to an equal extent, of everyday life, so much so, indeed, that its sudden suppression would cause vast confusion in a great number of instances. It in fact enters, under every size and shape, into the whole equipment of civilisation, from the railway buffer to the sight-piece of the chassepot." It would be an easy matter, at the present day, to enlarge to a much greater extent on the importance of this substance, the manufacture of which since then has increased by leaps and bounds. Prior, however, to discussing the present vast and multifarious uses of indiarubber, and the developments which the rubber industry has now assumed, we must, in the first instance, glance at its early history, a knowledge of the vicissitudes of which is in all industries so essential to the expert therein.

It was Gonzalo Fernandès d'Ovièdo y Valdas who first mentioned, in his *General History of the Indies* (Madrid, 1536, L. V., c. ii. p. 165), "the Indians' game of Batey, which is the same as the game of ball, although played in a different manner, and the ball is made of a different substance to that used by Christians." According to Morris, the first record of indiarubber was made soon after the discovery of the New World by Columbus. The Old World rubbers were still unknown. During the second voyage of Columbus, it was noticed that the inhabitants of Hispaniola (Hayti) played with balls made from the gum of a tree. This was fully 400 years ago. Father Xavier de Charlevoix, of the Society of Jesus, 1682–1761, describes the *Batos*, a species of ball of a solid matter, but extremely "porous and light. It soars higher than our balls, falls on the ground, and rebounds much higher than the level of the hand which it quitted; it falls back again, and rebounds once more, although not to such a height this time, and the height of the bounces gradually diminishes." Antonio de Herrera Tordesillas, the Spanish historian (born at Cuellar in 1549, died at Madrid in 1615), completed these data in 1601 in his *General History of the Voyages and Conquests of the Castilians*, in the islands and mainlands of the East Indies, and, in speaking of the ball used by the Spanish Indians, enunciates for the

first time, the descriptive term *gum*. The same author, whilst speaking about the conquest of Mexico, quotes, as one of the peculiarities of Cumana, certain trees which, when punctured, yield milk which becomes converted into *gum* with a fine smell. Jean de Torquemada, in his book of the *Monarquia Indiana* (Madrid, 1615), mentions the uses of the elastic balls, and calls the tree which furnishes the milky juice from which they were elaborated, *Ulaquahuil*, or the *Ulé* tree, a name still used by the natives to designate the *Castilloa Markhamiana* and the *Castilloa elastica*. The new conquerors, on their part, made

FIG. 1.—Full-grown Para indiarubber tree (*Hevea Braziliensis*) in a Brazilian forest.

use of rubber itself to coat their hempen cloaks, and thus protect themselves from rain; these were waterproof, but the intense heat of the tropical sun greatly affected them. At the court of Montezuma, in the ancient Aztec city which is now Mexico D.F., and the capital of the Mexican Republic, they played a sort of tennis in walled patios with balls of indiarubber. The tree which yielded the material for these earliest tennis balls was called Ulé (with certain variants), and it is known in Mexico and Central America amongst the Indians as Ulé to-day. [British scientists call the tree *Castilloa elastica*; American scientists call it *Castilla elastica*. There are many species, of varying commercial value, the best having been named

lactiflua. Brazil abounds in *Castilloa* trees, but the indiarubber obtained from them is inferior to the product of the Heveas, which yield the famous Para rubber. The Brazilian *Castilloa* rubber is known on the markets of the world as *caucho*, whence we get the variant caoutchouc, or it may be that the latter spelling is nearer to the original Indian word.] It is a singular fact, says Morris, that in the depth of the Guiana forests, in the remote Indian villages on the tributaries of the Amazon, and in the heart of Africa, similar rubber balls are still being used to play with. Often it is only in this way that travellers have become acquainted with the existence of rubber-yielding trees in the vicinity. Now and then, in these early days, some rare samples of the *elastic* product reached Europe to ornament the curiosity cabinets of the epoch. It was worth a guinea an ounce.

FIG. 2.—Six-months-old indiarubber tree (*Hevea Braziliensis*) growing in a modern plantation in Cochin, Southern India.

But, coming to a period when the history is more definite and precise, in 1731 the Paris Academy of Science organised two expeditions to solve the vexed question of the exact shape of the earth. One of these, under La Condamine and Bouguer, went to the equatorial regions of South America. Bouguer was an astronomer and a learned mathematician, and La Condamine was a Doctor of Medicine and an eminent naturalist. It is not therefore surprising that the latter should have profited by the opportunity of studying the fauna and flora of Peru and Brazil. In 1736, a short time after his arrival at Quito (capital of Ecuador), La Condamine

dispatched to the French Academy of Science some rolls of a blackish, resinous mass known under the name of caoutchouc. His parcel was accompanied by a memoir in which the following occurs :—"There grows, in the forests of the province of Esmeraldas, a tree called by the natives of the country *Hévé*; there flows from it, by simple incision, a liquor, white as milk, which gradually hardens and blackens in the air. The inhabitants make flambeaux of it, which burn very well without wicks, and give rather a fine light. . . . In the province of Quito, sheets of linen are coated with it, and are used for the same purpose as we use waxcloth. . . . The same tree grows along the banks of the river Amazon, and the Maïnas Indians call the resin which they extract from it *cahuchu* (pronounce caoutchouc). They make boots of it, which do not draw water, which, after having been blackened by holding them in the smoke, have all the appearance of real leather. They coat earthen moulds in the shape of a bottle with it, and, when the resin is hardened, they break the mould and force out the pieces through the neck and mouth; they thus get a non-fragile bottle, capable of containing all kinds of liquid." Pursuing his investigations, he describes the peculiar use which one of the tribes made of indiarubber. "The use which is made of this resin by the Omaguas, in the middle of the American continent, on the banks of the Amazon, is still more singular; they make bottles of it, in the form of a pear, to the neck of which they attach a fluted piece of wood. By pressing the bottles, the liquid which they contain is made to flow out through the fluted piece of wood, and by this means these bottles become real syringes." That is the origin of the name given by the Portuguese to the tree, which yields this rubber, *Pao de Ciringa* (syringe-wood), and of *seringarios* (seringueiros) to the rubber collectors. Preoccupied by his scientific researches, determining an arc of the meridian, Lacondamine could not continue his investigations on the indiarubber tree, and matters would have remained so if he had not found, in Fresneau, the French engineer stationed at Cayenne (an isle of French Guiana), a collaborateur as persevering as he was enlightened. Fresneau, who seems to have foreseen all the future importance of indiarubber, carefully inquired into its real source. No toil rebuffed him, not even the horrors of a residence in Cayenne, and finally he found among the Coussaris Indians the much-sought-after tree. In a note which he addressed to Lacondamine, he described the characteristics of the *gum* tree, and, at the same time, communicates the first exact notions as to the methods employed by the natives to obtain indiarubber. "They commence," he says, "by washing the foot of the tree; then they make, with a bill-hook, longitudinal but rather oblique incisions which should penetrate the whole thickness of the bark, taking care to make them, one above another, so that the flow from the top incision falls into the incision underneath, and so on, until the last one, at the bottom of which a leaf of the *Balisier* (an American reed) is placed, which is made to hold the liquid by potter's earth, so as to lead the juice into a vessel placed at the foot of the tree. To utilise the milky juice of the different trees which I have mentioned, all of which are resinous, a mould is made of potters' earth, according to the shape of the vessel which it is intended to make, and, to hold it more conveniently, a piece of stick is sunk in the place which is not to be coated with milky juice. An aperture is thus secured through which the potter's earth may be afterwards expelled, by introducing water to soften it. Any one mould being shaped, polished, and softened with water, it is coated all over with milky juice by means of the fingers, after which this coating is exposed to a denser smoke, where the heat of the fire hardly makes itself felt, keeping constantly turning it, so that the juice may be spread equally over the mould, and taking good care that the flame does not reach it, which would cause the milky juice to boil, and thus to form small holes. As soon as a yellow colour is seen, and this first coating is no longer tacky to the fingers, a second layer is applied, which is treated in the same way, and so on with the other coats, until it is judged to be sufficiently thick, and then it is kept longer over the fire so as to evaporate the whole of the moisture, until nothing but elastic resin remains, . . . finally, the objects will be the more substantial the greater the number of coats which have been applied. With this juice and linen

sheeting, tarpaulins, pump hose, divers' clothing, bottles, sacks for containing campaigning biscuits, etc., may be made, without fear of this material imparting any bad smell; but all these things can only be executed on the spots where the trees grow, as these juices *soon lose their fluidity*."

The communications of Lacondamine and Fresneau induced the French botanist Fuset-Ablet to start for Guiana in 1762, and two years later he published his *Flora of Guiana*, in which he gave a botanical description of the indiarubber tree, which he named *Hevea guyanensis*. A doctor of medicine of Penang or Prince of Wales Island, James Howison, was the first to determine, in 1798, under the name of *an elastic gum vine*, the species that later on was called *Urceola elastica* by Roxburgh, who, aided by Mr. Smith of Sylhet, discovered in the forests of Brahmaputra, in Assam, the *Ficus elastica*, the Assam rubber tree. The peculiar circumstances under which each of these trees were respectively discovered to yield indiarubber are so interesting as to merit description. With regard to the *Urceola elastica*, this tree was the principal source of supply from the East prior to the introduction of that from the *Ficus elastica*. Its importance seems to have been discovered by accident, towards the close of the last century, the circumstance being recorded in the *Asiatic Researches* of 1798. It appears from the narrative, that in clearing a way through the jungle with cutlasses in the island of Penang, the juice which had collected on the blades turned on drying into a substance possessing all the characteristics of indiarubber. The source of the juice was found to be a vine about as thick as a man's arm, which trailed along the ground for a great distance, sending out rootlets from each joint, and ultimately climbing to the top of the highest trees. The plant was introduced into various botanic gardens as a species of the genus *Hevea*, to which the well-known Para rubber with which it is still occasionally confused belongs. The earliest writer on Assam rubber was Dr. Roxburgh. His attention was first directed to the rubber as a waterproofing material on a vessel containing honey, sent to him in 1810 from Sylhet by Mr. Matthew Richard Smith. More recent writers assert that the natives of Assam have utilised the properties of gum-elastic for ages to waterproof baskets and to burn as candles.[1] Coffigny discovered in Madagascar a sarmentose plant of the jasmine species, which furnishes a milky juice which, in thickening, yields an elastic juice, like indiarubber.

Manihot Glaziowii muell. d'arg., the tree which produces the rubber known in commerce as Ceara, was exploited in Brazil for a considerable period before it was botanically identified. It was discovered by Dr. Glaziow, a French botanist, in the neighbourhood of Rio de Janeiro, Brazil, and was described and named after him by Mueller in Martin's *Flora Braziliensis*, xi., part ii.

Although some seventy species of *Manihot* are said to occur in Brazil, it was generally stated until quite recently that *Manihot Glaziowii* alone yielded rubber of commercial value, but it now transpires that a distinct species is being cultivated in South America. The latter plant appears to be well known in San Paulo, South Brazil, but it has not been botanically identified nor is it known how the rubber which it produces compares with that yielded by *Manihot Glaziowii*.

The utilisation of rubber for making articles for domestic purposes was not only practised by the natives of Central and South America, but also by the tribes inhabiting Assam, long before it was known to European nations. Ernst states that the "Cambibas, a section of the tribe Amaguas on the Upper Amazon, used rubber juice in pre-Columbian times to make waterproof vessels for carrying food and water, giving it the name of *caucho*, no doubt the original of our word caoutchouc." Further, it is related that in 1755 the King of Portugal, Don José, having heard of the wonderful waterproof materials used by the Indians, "sent several pairs of his royal boots to Para in order that they might be covered with rubber." It would appear to have been towards the end of the eighteenth century

[1] In any case, Assam rubber was unknown in Calcutta in 1828, as, when an upcountry gentleman sent some to his Calcutta agents, they replied, "the article being unknown in this market, we are sorry we can give you no idea of its value."

before rubber was imported into Great Britain, where the name of indiarubber was first given to it owing to the facility with which it removes black-lead (graphite) pencil marks. Whilst botanists were accomplishing their task, chemists studied the new resin, and succeeded in dissolving indiarubber.[1]

1761.—Hérissant and Macquer published the first technical monograph on indiarubber "études sur les racines du caoutchouc de cayennes," and in 1763 addressed memoirs simultaneously on caoutchouc to the Paris Academy, and enumerated *Dippel's animal oil*,[2] *spirits of turpentine*, as well as *pure ether*, as bodies capable of softening and even of dissolving the elastic resin insoluble in water and alcohol. They proposed to use this resin, softened in this way, in the manufacture of medicinal probes and small tubes for use in laboratories. 1770.—The English chemist Priestley (1733–1804) called the attention of the scientific world to the use of indiarubber. He recommended the use of the "rubber" for effacing pencil marks. 1772–75.—It was Magellan who spread this method in France, and, at the stationers' shops in France, as far back as 1775, small cubes of indiarubber could be obtained, which were for the nonce called *peaux de nègres* (niggers' skins), but in England the name *indiarubber* has been definitely retained. 1780.—The experiments of Bernard, a French chemist, completed the work of Macquer and Hérissant, and forecasted the numerous applications which could one day be made of indiarubber. Between times, Faujas de St. Fond occupied himself with a sort of bitumen found in the mines of Castleton (Derbyshire), and which he did not hesitate to term *mineral caoutchouc.*

1780–1820.—Fourcroy (1735–1809), like Hérissant and Macquer, acted on rubber with ether and caused it to swell therein. Berthollet (1748–1822) and Giobert also studied indiarubber, whilst Grossart made known the most convenient way for making, from the Brazilian indiarubber, bottles, and all the tubes and other articles which are required not only for physical or surgical purposes, but also for domestic use. In order to prepare small tubes, he cut the bottles into thin narrow strips of the most suitable shape, and after they had been softened and become swollen, by having been immersed in ether for half an hour, or a little longer in essential oil, he rolled the strip on a mandrel, and pressed the substance strongly by means of a bandage twisted into a spiral. In drying, the surfaces amalgamated, and the objects so prepared preserved the form which had been given to them. Payen gives a somewhat different account of the way in which Grossart made his tubes. The cut strips were twisted into a helix and moulded on to slightly conical glass tubes. These were rendered durable and uniformly flexible by applying them as an envelope round brass or steel *springs*, termed *bretelles.* We shall only cite in passing the attempts—more or less fortunate—of Charles the physicist, in 1785, to coat his aerostat with rubber dissolved in turpentine (spirit), of Besson (1791–93), of Johnson (1797), of Champion (1811), of Clark (1815), for rendering clothing waterproof by solutions of indiarubber, and finally arrive at the year 1820, which gave birth in real earnest to the indiarubber industry.

1820.—The English mechanic Nadier discovered at this time the means by which indiarubber could be cut into thread, and to make from it articles in common use and elastic fabrics, to replace advantageously the brass wire rolled in spirals. In this year James Hancock established in England the first rubber manufactory.

1823.—Mackintosh discovered and applied a solution of indiarubber in coal-tar

[1] From 1736 till 1770 it appears to have been a mere curiosity. In that year it was introduced to the British public for the purpose to which it was long almost exclusively devoted, and from which it has derived its familiar name. In the preface to a book on perspective, published in that year, the following interesting passage occurs: "Since this work was printed off, I have seen a substance (no name is given to it) excellently adapted to the purpose of wiping from paper the marks of a black-lead pencil. It must, therefore, be of singular use to those who practise drawing. It is sold by Mr. Nairne, mathematical instrument maker, opposite the Royal Exchange. He sells a cubical piece of about half an inch for three shillings, and he says it will last for several years." Translator's note to 2nd English Edition.

[2] Bone naphtha.

naphtha, and thus created the waterproof garment industry which took the name of the inventor. Reithofer of Vienna made simultaneous experiments on garments. But the use of indiarubber presented numerous difficulties; the substance was not very easy to manipulate, required special plant, and the methods adopted for effecting solution—still imperfect—rendered it difficult to impart to indiarubber articles any well-determined shape.

1830.—About 1830 Rattier and Guibal applied the property of the non-extensibility of rubber stretched in the cold to weave indiarubber threads (in chain); they made laces which, heated to 40° C., contracted and resumed their primitive elasticity. Very excellent goods were produced in this way, but liable to harden in cold weather. The first French rubber factory was established at Clermont Ferraud in 1830.

1836.—These obstacles were surmounted in the end of 1836, when it was found, in consequence of the researches of Thomas Hancock in England and Chaffe in America, that indiarubber cut into small strips, or shredded and submitted to energetic kneading under the influence of a moderate heat, could be reduced into thick masses, that its elasticity could for the moment be suppressed, and that, in this state, it was capable of assuming whatever form was desired to be impressed upon it. The manufacture of indiarubber articles of daily use was henceforth a solved problem; the discoveries of Rattier, Guibal, Aubert, and Gerard succeeded each other rapidly, and caused the industry to make remarkable progress. Bernard used the heavy oils from rubber distillation in varnish making, and Nikel of Vienna first produced laminated sheets.

Vulcanisation.—This progress, however important, would have remained barren, and the very existence of the new industry would have been in peril, without one of those opportune inventions of which last century furnished so many notable examples. Indiarubber goods are subject, without exception, to a great defect proceeding from the deterioration of their elasticity under different circumstances and conditions. In fact, indiarubber is very elastic at the ordinary temperature; it is so to such an extent that a thread may by a pulling force be stretched to five or six times its original length, to resume its natural length if the cause which produced the elongation ceases to act. Cold causes it to lose this property: it becomes hard, and if it be attempted to elongate it in this condition, it breaks. In the heat of summer, or under the influence of artificial heat, the elasticity is restored. But natural indiarubber, besides its impermeability and elasticity, possesses a very energetic adhesive property, especially in contact with itself. This property, utilisable for indefinite elongation of threads and sheets, for example, is extremely injurious in the manufacture of certain articles. In the heat of summer this adhesiveness is still further accentuated; the indiarubber becomes tacky and pitchy, whilst at the same time it gives off a very disagreeable smell. The grave nature of the defects of crude indiarubber will be better understood from a few examples. One of the first industrial applications of indiarubber, as has been already mentioned, was the waterproofing of garments. Though excellent against rain, these garments split and broke under the influence of cold, however feeble its intensity; they became viscous, and in summer, on the other hand, under the action of the sun's rays, they became tacky. It was the same with indiarubber shoes, *goloshes*, *souliers indiens*, which, whilst they were not very graceful in shape, were at first well patronised by European fashion. But very soon the consumer did not want any more of them at any price. *Mackintoshes*, as then made, shared the same fate.

1832.—Going back a little to pick up the thread of the history of *vulcanisation*, the German chemist Ludersdorf, famous for his alcohol vapour lamp, was the first, in 1832, to observe that sulphur removed the viscosity of indiarubber dissolved in spirits of turpentine. He afterwards claimed the discovery of vulcanisation.

1839.—The Hayward patent, taken out by Goodyear on 24th February 1839, pointed out the changes induced in indiarubber under the action of sulphur, but it indicated neither the proportions nor the temperatures under which the reaction

is rationally conducted. Flowers of sulphur was used to dust over sheet-rubber and thus attenuate the clammy adherence of the gum.

1844.—Goodyear, who seems to have been the prime mover in the Hayward patent, seems to have been somewhat dilatory in following the matter up. But in 1844 he described how he had solved definitely, in 1839, the question of the industrial production of an indiarubber neither brittle at low temperatures nor tacky at high temperatures. He described the properties which sulphur imparted to rubber by combining therewith, and the process was henceforth known as *vulcanisation*. Goodyear's discovery consisted in submitting natural indiarubber, first to the action of sulphur and then to that of rather a high temperature. The term *vulcanisation* was given to this process, and the indiarubber so treated was termed *vulcanised indiarubber*. Vulcanised indiarubber preserves its elasticity at a low as well as at a high temperature up to 120° C. (248° F.); moreover, it resists better the action of chemical reagents. Vulcanisation gave an impetus and development to the indiarubber industry that henceforth had no bounds, and, during a period of twenty successive years, each day brought its contingent of discoveries and improvements in the new industry, which had just made its exit from the embryonic stage of development. If Goodyear patented his process of vulcanisation by mechanical mixture, his fortunate and very inventive rival, Hancock, took out a patent in 1844 for vulcanisation in a sulphur bath. Parkes, the chemist who in 1843 had already discovered a better process of dissolving indiarubber by a new vehicle, carbon disulphide, patented in his turn a method of vulcanisation called the steeping or immersion method (*au trempé*), or vulcanisation in a bath of chloride of sulphur. We owe to the same chemist the first process for desulphurising vulcanised indiarubber waste. Peroncel and several other manufacturers improved the sulphur chloride process by applying it to the manufacture of a whole host of products used in the industrial arts, surgery, and domestic economy. Guibal made by the aid of talc and indiarubber, mixed into a paste, a cylinder from which thick rings were cut. The first vulcanised rubber boots were made at Vienna by Reithofer in 1850.

Austin H. Day took out a patent in 1858 for improved vulcanisation, and Gerard proposed the alkaline sulphides for the vulcanisation of thin objects. Finally, the series of grand discoveries terminates in the invention of *hardened rubber* or *ebonite*, likewise due to Goodyear. This indefatigable investigator was able by a more energetic treatment of the indiarubber, by means of sulphur, to transform it into a horny mass analogous to whalebone and even to ivory.

Hancock's patent.—Up to this point no mention has been made of the patent taken out by Hancock in 1846 for moulding objects in caoutchouc, an invention which was the starting-point of solid moulds, buffers for railway rolling stock, etc., valves, engine and machinery belts, then of hollow moulds (toys, etc.). These are important advances without doubt, but not indispensable to the forward march of an industry which has created itself all in one piece, so to speak, and which certainly has not had its last say.

Later researches, developments, and improvements are fully described in the sequel. These at the present day all tend towards scientific tapping and the production of pure well-coagulated rubber, thoroughly washed and dried, in one word, cured on the spot by the planter in the most rapid, thorough, and effective manner possible. But what gave to the indiarubber industry the greatest impetus it ever received, was undoubtedly the re-invention by Dunlop of the pneumatic tyre previously suggested by Thomson, the forerunner of all the tyres now used so extensively in many branches of locomotion.

CHAPTER I

INDIARUBBER, LATEX; DEFINITIONS; LATICIFEROUS VESSELS; BOTANICAL ORIGIN, HABITATS

SYNONYMS.—English, *Elastic*, *Gum Elastic*, *Caoutchouc*; Latin, *Gummicum Elasticum*; French, *Le Caoutchouc*, *Gomme Elastique*, *Gomme*; German, *Gummi*; Spanish, *Seringa*; Portuguese, *Xirringa*.

Definition.—Indiarubber is a hydrocarbide [1] of vegetable origin, extracted from the juice secreted by the protoplasm of a so-called primordial cellular tissue of a great number of trees, shrubs, and vines, climbers or bindweeds of hot countries. The principal vessels of this tissue are situated in the inner layers of the bark, outside the liber bundles and their sclerose sheath (when it exists). They send out numerous branches, some outwards, across the bark to the epidermis, where they terminate in a *cul de sac*; the others, less numerous towards the interior, cross the endodermis and the medullary rays to the pith, around the periphery of which they diverge longitudinally. This carbide of hydrogen [1] and its derivatives, the issue of the activity of the protoplasm, would not appear, at least according to certain naturalists, to be afterwards employed in the life of the plant, and it is considered by them as a product of elimination, a reserve product, utilised by man in the arts and industries. Other men of science, with whom we more readily agree, consider this carbide necessary, at least partially, to the life of the plant.

The Latex.—If an incision be made on rubber-bearing plants, there flows from it a milky juice, having some resemblance to the milk of the goat; the *latex*, collected therefrom, under suitable manipulation, abandons its suspended microscopical globules to form a more or less white solid matter, which is *indiarubber*. These globules have a diameter of not more than two to three micromillimetres [2] (Adriani). Where the latex is abandoned to itself, the globules gradually separate from the aqueous liquid, and form a true cream on the surface. In narrow vessels, they aggregate into flakes, distributed through the whole liquid. The properties of latex may be summed up thus: it possesses the density of cream, is slightly amber-coloured, mixes with water, but not with naphtha or any other solvent of indiarubber. Its specific gravity varies between 1·02 and 1·41, whilst that of caoutchouc is 0·930. In regard to its percentage of pure rubber, it varies considerably; the typical latex, that of Para (Brazil), is composed as follows:—

TABLE I.—TYPICAL ANALYSIS OF PARA LATEX.

	Per cent.
Pure indiarubber	32
Albumenoid extracts and mineral water	12
Water	50

[1] The terms carbide of hydrogen and hydrocarbide show the direct relationship of this class of compounds to the metallic carbides better than the misleading term *hydrocarbon*.

[2] A micromillimetre = the thousandth part of a millimetre.

The rubber-yielding milky juice of caoutchouciferous plants is a watery fluid, containing diverse substances in solution, in which there are suspended minute globules of rubber. The milkiness of the juice is due to the difference in the refractive power of the solution and the suspended globules. The latex falls to be differentiated from the juice, from which it essentially differs. The latex is, as a matter of fact, a *secretion* and (some say) not at all indispensable to the well-being of the plant. Hence comes the idea that the plant would be perfectly healthy and discharge all its functions normally if the latex were collected from it in a rational manner and by a system of tapping which did not injure the vegetable tissues to any great extent. But, in any case, some slight incisions must be made to start the flow. The goal at which we should aim is to obtain the largest flow of the best quality of latex in the shortest period of time, and with the least permanent injury possible to the rubber-producing tree and to the soil.

Laticiferous vessels.—The system of *laticiferous* vessels of caoutchouciferous plants would appear to G. David to be simple isolated cells which follow the elongation, and, at the same time, send laterally, across the meatus of the ambient tissue, ramified branches which are prolonged into the leaves. These branch laticiferous cells belong not to a fibro-vascular bundle, but to the fundamental parenchyma. G. David's observations are quite in accord with the micrographical researches of Trécul, C. R., 1865 (2° *Semestr.*, page 159 and page 294). It is necessary to differentiate between the morphological structure of the various systems of laticiferous vessels of the different families to which the individual indiarubber plants belong. According to Sach's *Treatise on Botany* (Paris, 1874), *the system of laticiferous vessels of the Urticaceæ*, very highly developed especially in the *Ficus*, threads its way through the bark, in the immediate neighbourhood of the liber fibres; it is also found in the pith of the *Ficus*, never in the wood. But these vessels are neither so abundant, nor so decidedly articulated, as in the *Papaveraceæ*, nor so regularly anastomosed in a network of narrow meshes, as in the *Chicoraceæ*. They travel between each internode of the stem, side by side, almost isolated, like long, uninterrupted, cylindrical tubes, which, but rarely, send out lateral branches, and only communicate, here and there, with the neighbouring tubes. In the nodes, on the contrary, and in the leaves, they assume numerous ramifications, at times anastomosed in a network, and form small, fine prolongations terminated in a finger-stool. In the thick leaves of several fig-trees they spread far through the parenchyma, and even come in direct contact with the epidermis.

Laticiferous vessels of the Euphorbiaceæ, Apocyneæ, and Asclepiadeæ.—The laticiferous vessels of the *Euphorbiaceæ* resemble the preceding, in so far as they likewise ramify, and are abundantly distributed throughout the whole of the fundamental tissue, but they differ from it because their sides are thicker, and resemble, in transverse section, the liber fibres; attaining their greatest development in the neighbourhood of the latter, which they sometimes entirely replace. From this point they send out branches into the bark and into the pith, forming numerous ramifications especially in the nodes of the stem and the armpits of the leaves. The laticiferous vessels of the *Asclepiadeæ* and the *Apocyneæ* have a still greater resemblance to the liber fibres; like the latter they are (1) partly pointed at the two ends, and (2) their sides are sometimes thickened and streaked in a characteristic manner. Sometimes they occupy essentially the place of true liber fibres, whilst on other occasions they are united and mixed with them in the liberian bundles, moreover they sometimes surround them. It is, therefore, by the simple presence of the milky juice that the relationship of these transformed liber fibres, with the true laticiferous vessels, is recognised; the more milky their contents, the thinner does their cell-wall become. Besides the simple and fibrous elements, ramified and anastomosed tubes are found, which are more especially abundant in the nodes, in the pith, and the bark.

Differentiation of rubber from milky juice of plants of temperate climates.—The flora of temperate countries include a large number of plants with a milky juice, but these juices do not always contain indiarubber; and, even when they do

contain it, it is too often present in such small quantities that its industrial working would not be profitable. The nettles, the poppies, the lettuces, the castor oil plant, the fig-trees, etc., *of our temperate climate* cannot, therefore, be considered as indiarubber-yielding plants, and there can be no question of obtaining rubber from them on a large scale. Of the several hundred plants endowed with a milky juice, as yet, no more than fifty contain indiarubber in such a proportion as would pay for the cost of extracting it.

Rubber-producing zones.—Only the tropical and intertropical zones, from the 30° N. lat. to the 30° S. lat., yield plants of a certain economical value, so far as the question now at issue is concerned. There, a vast belt of land, 800 kilometres (say 500 miles) wide, encircling the globe all round the Equator, fulfils all the conditions requisite for the production of indiarubber plants of commercial value. There, a moist warm climate prevails at one and the same time. The temperature generally varies from 26° to 42° C. (from, say, 80° F. to 108° F.), whilst the mean average rainfall is 2·09 metres (say 81½ inches). Some authorities restrict the indiarubber zone to 25° or 28° north and south of the Equator. This zone is divided by Drude into—(*a*) the tropical American, including the West Indies; (*b*) the tropical African, including Madagascar; and (*c*) the Indo-Malay region, including Oceania. The world's supply of indiarubber is drawn exclusively from these three regions.

Botanical origin of rubber-producing plants.—The plants which yield the indiarubber latex are not always of the same species, nor are they even of the same botanical order over the whole extent of the indiarubber zone. They belong to different botanical orders, more especially (1) to the *Euphorbiaceæ* or spurgeworts; (2) to the *Artocarpeæ* family of the *Urticaceæ* or nettles; (3) to the *Apocynaceæ* or dogbanes; (4) to the *Asclepiadiaceæ*; and (5) various other orders. But an appreciable difference exists between the various species of the same order, not only in regard to the quantity but in an equal degree to the quality of the indiarubber which they yield. The indiarubber-yielding plants of tropical America are chiefly arborescent, *Hevea Braziliensis*, *Manihot Glaziowii*, *Sapium biglandulosum*, *Castilloa elastica*, etc. A few shrubs like *Parthenum argentatum*, etc., and climbers like *Fosteronia floribunda*, also flourish there. The African rubber industry, including that of Madagascar, depends mainly on climbers (vines), or as the French term them, *lianes*. Such are the various species of the genus *Landolphia*, *Clitandria*, *Carpodinus*, *Cryptostegia*. But lately trees indigenous to Africa have yielded an appreciable amount of rubber, and have thus brought a notable contingent to swell the supply from the climbers. The rubber of the Indo-Malay region is secreted by (1) gigantic trees, *Ficus elastica*, *Sapium insigne*, and by (2) climbers, *Cryptostegia*, *Willughbeia*, *Urceola*, *Leuconotis*, *Parameria*. The characteristics of the species introduced into and acclimatised in these different zones and rationally cultivated therein will be described in their proper place.

As will be seen later on, the quantity of commercial indiarubber does not depend solely on the plant producing it. Many other determining causes intervene to increase or diminish the production of the latex, and to determine the production of superior or inferior quality latex. But, *ceteris paribus*, the most superior grades of rubber are produced from plants belonging to the natural order *Euphorbiaceæ*, the botanical characters of which are now given.

1. Natural Order *Euphorbiaceæ* (spurgeworts); tribe *Crotoneæ*.—Essential Character.—*Flowers*, monœcious or diœcious. *Calyx*, none, or lobed, inferior, with various glandular or scaly internal appendages. *Males*: *Stamens*, definite or indefinite, distinct or monadelphous; *anthers*, two-celled. *Females*: *Ovary*, superior, sessile, or stalked, three-celled; *ovules*, solitary or twin, suspended from the inner angle of the cell; *styles*, three; *stigma*, compound or single. *Fruit*, consisting of three dehiscent cells, separating with elasticity from their common axis.—*Trees*, *shrubs*, or *herbaceous* plants, often abounding in acrid milk. *Leaves*, opposite or alternate, simple, rarely compound, usually with stipules. *Flowers*,

axillary or terminal, usually with bracts, sometimes enclosed within an involucre. The fruit of this order is tricoccous, that is, it consists of three carpels, which, when ripe, separate from each other with some elasticity, opening by the edge next the axis; this, together with the unisexual flowers, distinctly marks the order. The *Euphorbiace* yield as rubber-producing plants (1) the *Hevea*; (2) the *Micrandra*; (3) the *Manihots*; (4) the *Euphorbia*; (5) *Sapium*. In addition to several genera of rubber plants, this large order of 290 genera and 2500 species yields such economic products as teak, castor oil, ipecacuanha, and tapioca.

(1) The *Hevea* (Figs. 1, 2, and 3) is a genus of the *Euphorbiaceæ*, tribe *Crotoneæ*, which gives its name to the series of Heveas. The flowers, diœcious and apetalous, have a five-lobed valvular or subinduplicate calyx. The lobes are sometimes slightly twisted at the summit. Their andrœcium consists of five

FIG. 3.—*Hevea Braziliensis.* Flowering Twig.

alternisepalous stamens; or six to ten, on two alternate whorls. They are reduced to extrorse, bilocular anthers, dehiscent along the longitudinal slope [loculicidal], and sessile on a central stalk ornamented and terminated by a sterile gymnœcium. The disc, sometimes absent or rudimentary, is generally developed round the base of this stalk. In the female flower, the uniovular, trilocular ovary surrounded by distinct glands, connate, or sometimes inconnate, is surmounted by a style in the form of a very short stalk, which is terminated by stigmatiferous, fleshy, and bilobed lobules. The fruit, which, according to Aublet, would appear to be edible, is a three-shelled capsule, each of which is dehiscent by means of two elastic valves. The exocarp, become fleshy before maturity, is easily separated from the endocarp. They are large trees, with an abundant milky juice, alternate leaves, elongated petioles, digitate, on three sessile or petiolated

leaflets, feather veined and glandular at the base. Their flowers are arranged on compound *racemes*, composed of axillary and terminal *cymes*. The central flower of the cyme is generally female. The tree reproduces itself with the greatest of facility; the envelope which contains the seed bursts with a noise like the detonation of a capsule of fulminate of mercury, and the seed is projected in the neighbourhood to a distance of about 50 to 80 feet. Reproduction was left to nature by the natives. The tree is upright, and grows to a large size up to 60 feet in height, with a conical trunk 6 to 8 feet in circumference. The top branches, when the trees grow closely together, are short, the leaves are compound and trifoliate. The whitish-green flowers are male and female in the same panicle, the female usually large and terminal. The fruit is a large dry capsule composed

FIG. 4.—*Manihot Glazowii.* Young branch (half its natural size); inflorescence (half its natural size); half-ripe fruit (its natural size).

of three one-seeded pieces. The wood is white and soft, and forms bad timber. It is an error, which prevailed until lately, to regard the *Hevea Guyanensis* (the *Jatropha elastica* of Linnæus and the *Siphonia elastica* of Schreber) as being the real tree called *Seringa* or *Cahuchu* by the Indians of Brazil, and as constituting the indiarubber tree *par excellence*. This is indeed the tree mentioned by Lacondamine, but it yields a scanty latex, which is very poor in resinous globules. The dry extract which is obtained from it is of a very inferior quality. The *hevea* which produces the most esteemed commercial rubber, is the *Hevea Braziliensis* (Muller d'Arg.), or *Siphonia Braziliensis* (H. B. K.).

(2) The *Micrandra* (Benth.) is a genus of the *Euphorbiaceæ* of the tribe of *Crotoneæ*, with monœcious flowers, with valvular or imbricated petals, a petandrous andrœcium, trilocular ovary, the fruit opening tardily or scarcely. They consist of

three or four species of trees, with alternate leaves, which came originally from Brazil. Their latex is said to contribute its contingent to the supply of Amazon rubber.

(3) The *Manihots* (Plum-Adams).—A detached species of the *Crotoneæ*, of which it possesses the characteristics with male decandrous flowers, if its perianth be not unique, gamophyllous, with five short divisions with a large disc in bisexual flowers. They consist of about seventy-five American herbs or shrubs, with alternate leaves, digitate lobed, or partite. Their root is often swollen and rich in starch. The *Manihot Glazowii* (Fig. 4) or *leitera* yields the *Ceara Scraps* of commerce or the *Manisoba* of the natives; it is the indiarubber tree of granitic land, high and dry, just as the *hevea* is the indiarubber tree of low-lying, well-

FIG. 5.—*Castilloa elastica.* Male flower-bearing branch.

watered ground, of which a clay, rich in vegetable mould, constitutes the principal essential.

2. NATURAL ORDER *Urticaceæ*, or nettle family.—The natural order is too well known to need any botanical description here. It supplies as rubber-producing plants (1) the *Castilloa*; (2) the *Ficus*; (3) the *Artocarpus*; (4) the *Acropia.*

(1) The *Castilloa* (Fig. 5) is a genus of the *Urticaceæ*, tribe *Artocarpeæ*, whose monœcious flowers, very analogous to those of the *pseudolmedia*, are united on distinct capitula, almost flat, or induplicated, reniform, and surrounded by numerous imbricated bracts, constituting an involucre. The males, consisting of numerous stamens, have no perianth. The female flowers unite in numerous glomerules, on a common receptacle. They possess a calyx with four divisions, a semi-inferior, uniovular ovary, surmounted by a thin cylindrical style, and divided at the summit

into two stigmatiferous, linear, awl-shaped, compressed, and sometimes convoluted branches. The fruit is a drupe, which is almost dry at maturity, adhering, on one side, to the calyx, and containing an exalbuminous seed, with a sub-globular embryo with thick, almost equal cotyledons, and a short superior radicle. It is a tree with a milky juice, generally pubescent, with distichous leaves, unequal at the base, and accompanied by supra-axillary and acute oblong connate stipules with unisexual, axillary stipite, fasciculated, rarely numerous, often solitary inflorescences.

(2) The *Ficus* (Fig. 6), a genus of the *Urticaceæ*, suborder *Artocarpeæ*, characterised by unisexual flowers, contained in a globular or pear-shaped receptacle more or less open at the summit. The male and female flowers, agglomerated together, sometimes exist together simultaneously in the same receptacle, and, in such a case, the males occupy the upper part; more generally, however, the sexes are placed in separate receptacles. The calyx is formed of two to six leaflets, and is often fleshy, four to six stamens, opposite the sepals, or sometimes only one stamen (*urostigma*) or two stamens (*pharmacosycea*); the pistils are free or connate at the

FIG. 6.—*Ficus elastica*. Branch.

base; the anthers are introrse, with two longitudinal sutures; ovary sessile or stipite generally unilocular, very rare bi- or trilocular, surmounted by a style, inserted laterally, enclosed in the receptacle, with a stigmatic infundibuliform or bifid surface. Ovule descending, anatropous, or campylotropous, with micropyle superior and turned outwards. Fruits, drupaceous, contained in a closed receptacle; mesocarp thin, membranous, often decidedly awanting; kernel crustaceous or fragile, with a single descending seed, provided with a fleshy albumen. The various kinds of *Ficus* are large trees or shrubs, and sometimes climbing plants, latescent, generally with alternate, rarely opposite, leaves, very variable in form in even a single species, entire or lobed, persistent or caducous, accompanied by broad stipules which at first envelop the terminal buds, and become detached often very promptly. The inflorescences are axillary, solitary, or fasciculated, or, more rarely, arranged in terminal spikes or clusters. The genus *Ficus* is one of the most important of the vegetable kingdom,—more than 600 species are known scattered over all the regions of the globe; but it is principally in the Malay islands and

the islands of the Pacific Ocean that the species attains its maximum development. The *Castilloa* being the indiarubber tree *par excellence* of Mexico and Central America, the *Ficus* is more especially the indiarubber tree of Eastern Asia and Oceania. It is only occasionally met with in Africa and America. One of the varieties of *Ficus* is very familiar to us in Europe, where, under the name of india-rubber plant, it constitutes one of the ornamental plants of our hothouses, gardens, and apartments. In order to thrive in our climate, this plant requires a moderate hothouse temperature, or simply that of the *orangerie*, and it can very well pass part of the year in the open air; it is brought indoors before the first frosts. Cultivated in pots, it preserves its lustre for a long time; in order to revivify it when weak, or to cause it to develop better, it is transplanted to the ground itself in an open-air greenhouse. Propagation is easy, and is done in mould or loam, under a hotbed, beneath a bell glass, by means of slips, cuttings, or branches, bearing two or three leaves, or even one only and provided with at least one bud. A light, substantial soil, rich in mould, kept very fresh during the period of vegetation, is that suitable for indiarubber.

(3) The *Artocarpus* (Figs. 7 and 8) (*Lin.* αρτος tree, καρπος fruit, bread-tree).—A genus of *Urticaceæ*, which gives its name to the series of *Artocarpeæ*, described by several authors as a distinct family, under the name of *Artocarpaceæ*. Its

FIG. 7.—*Artocarpus incisa*. Flowering branch and fruit.

flowers are monœcious. The male flowers have a more or less deep and imbricated two to four-lobed calyx, a single stamen with a central smooth pistil and smooth anther, bilocular and dehiscent by two sutures. The female flowers have a tubular receptacle, very concave, dug like a well on the common receptacle of the inflorescence, the sides of which bear a gamophyllous perianth, sometimes at the summit, whilst in the bottom a sessile or short stipite ovary is inserted, free, and surmounted by a lateral or central style, enclosed or exposed, simple or two to three-lobed at its stigmatic extremity. This ovary is, originally, bi- or trilocular, the only one persistent division of which in the adult stage contains in its internal angle a thick placenta, on which is inserted a descending anatropous ovule, with the micropyle superior, exterior, and often covered by an obturator. At maturity each ovary becomes an achene, the descending seed of which contains under its integuments a curved, exalbuminous embryo, generally with very unequal cotyledons. The aggregate of all these achenes, enclosed in the mass of the receptacle, which often becomes

starchy, constitutes a compound spherical or oblong fruit. Of forty odd species of *Artocarpus* known in Asia and Oceania, only five are commercially important in India. They are trees with a milky juice, soft wood, alternate entire leaves, or divergently cut, and accompanied by two lateral connate stipules in a broad, supra-axillary sheath which envelops the young branch, and leaves, after it sheds itself, a linear annular cicatrice. The flowers are arranged in glomerules in distinct receptacles, that of the males in the form of a cylindrical or claviform spike, furnished, on its exterior surface, with sessile flowers, generally intermingled with peltate bracts, whilst the females are arranged, in the receptacle, in the depression referred to

FIG. 8.—*Artocarpus incisa.*

above. Its viscous latescent latex is used by the Indians to make bird-lime. But it is especially valued on account of its fruit in Oceania (Taïti). It is a tree which may rise to a height of 50 to 80 feet, with a trunk as large as a man's body.

(4) The *Cecropia* (Lœfl.).—Genus of *Urticaceæ*, belonging to the family of *Conocephaleæ*, distinguished by its diœcious flowers in very dense spikes. Perianth of the male flowers, open at the summit by two pores; stamens two, exsert with short filiform filaments with bilocular anthers; perianth of the female flowers, tubular, entire, or almost entire, slightly thickened at the summit. Ovary free, unilocular; terminal stigma, subsessile capitulum. Monospermous achene, recovered by the persistent perianth. Ovules inserted on the summit of the dissepiment descendant, with a micropyle directed above and outwards. Seeds

numerous. A tree with knotty branches, fistulent in the internodes, alternate palma-bilobed leaves. *Habitat.*—Central and Equatorial America.

3. NATURAL ORDER *Apocynaceæ* (dogbanes). — ESSENTIAL CHARACTER. — *Calyx*, divided into five, persistent. *Corolla*, monopetalous, hypogynous, regular, five-lobed, with contorted æstivation deciduous. *Stamens* five, arising from the corolla; *filaments*, distinct; *anthers*, two-celled, opening lengthwise; *pollen*, granular, globose, three-lobed, immediately applied to the stigma. *Ovaries*, two, polyspermous; *styles*, two; *stigma*, one. *Fruit*, a double follicle. *Trees* or *shrubs*, usually milky. *Leaves*, opposite, sometimes whorled, seldom scattered, quite entire, often having ciliæ or glands upon the petioles, but with no stipules. They are readily known by their opposite leaves, and bifollicular fruit, from all orders except *Asclepiadaceæ*; and from that order by their separate anthers having powdery pollen. The *Periwinkles*, *Vinca major* and *minor*, common trailing shrubby evergreens, and an *Apocynum* or two, are the plants of this order which inhabit Europe.

But the *Apocyneæ* or *Dogbanes*, noted in tropical Africa for valuable rubber-yielding species, yield the *Vahea*, the *Landolphia*, *Funtumia*, *Mascarenhesia*, *Clitandra*, *Carpodinus*, and amongst other genera in various parts of the tropics noted for their rubber are the *Urceola*, *Dijera*, *Hancornias*, *Camcraria*, *Parameira*, *Leuconotis*, *Anodendron*, *Alstonia*, *Chenomorpha*, *Xylinabaria*, *Tabernæmontana*,

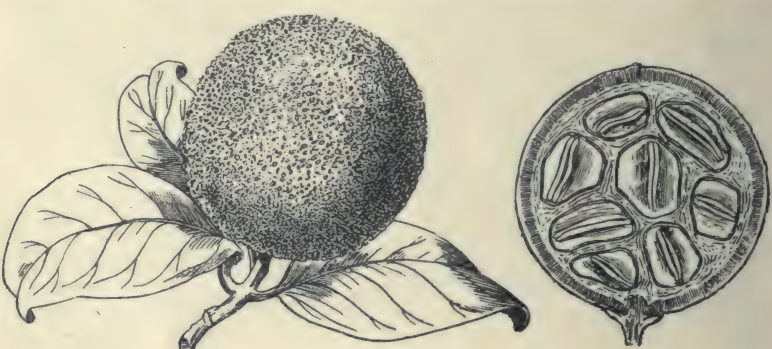


FIG. 9.—*Vahea.* Entire fruit and longitudinal sections.

Willughbeia, *Hymenelopus*, *Diplorhynchus*, *Fosteronia*, *Ecdysanthera*, *Micrechites*, etc.

(1) The *Vahea* (Fig. 9), a genus of *Apocynaceæ-crotoneæ*, formed by some twenty climbers of Central Africa and Madagascar, distinguished by terminal cymes with corolla flowers bearing the stamens near the base of the tube, the divisions of the limb narrow; fruit, a large bay with numerous angular seeds, the albumen of which is horny (see *Landolphia*).

(2) The *Camcraria* (Muller).—A genus of *Apocynaceæ*, of the series of the *Plumericæ*, sub-section of the *Euplumerieæ*, distinguished by the absence of a disc in its flower, and by its stamens, the anther of which is surmounted by a long filament. The two carpels enclose numerous ovules, arranged in twos, in their ovarian portion; ripe they become two indehiscent, top-winged, hardened samaras. They are West Indian glabrous shrubs with opposite leaves, and flowers in terminal cymes. The *C. lucida et latifolia* (Jack) yields indiarubber.

(3) The *Parameria* (Benth.).—Genus of *Apocynaceæ*, allied to the *Ecdysanthereæ*, distinguished by a calyx with several interior glands, a five-lobed corolla, the lobes covering over, by their left end, the elongated fruits, swollen to the utmost with seed. It consists of two or three vines of tropical Asia and Oceania. We have, provisionally, named a Cambodian species which yields excellent india-rubber, *P. Pierrei.*—*P. Glandulifora*, often confused with *Willughbeia edulis*,

is a large climbing evergreen shrub of the borders of the tidal forests of Tenasserim and Andaman Isles.

(4) The *Leuconotis* (Jack).—Genus of *Apocynaceæ*, consists of two latescent shrubs of the Malay Archipelago, distinguished by four primitive flowers, with a bilocular ovary, the dissepiments containing two ovules. The fruit is fleshy, and the seeds are exalbuminous. *Leuconotis Eugenifolicus*, milky evergreen shrub, of Penang, Malay Peninsula, Sumatra, Borneo, with smooth bark, leaves dark brown above, paler beneath, yellow brown minutely dotted, with strong horizontal nerves, fruit the size of a gooseberry, furnishes some of the Straits Settlement rubber known as gregrip sundik (Ridley) which, with that from *L. Anceps* of Borneo, is very poor in quality, whilst that from *L. Elastica* of Borneo is excellent. The latex from *L. Tubavenis*, Borneo, is used as an adulterant.

FIG. 10.—*Landolphia owariensis.* Branch.

(5) "The *Landolphia*," says Dewevre, "are all, according to what we know up to the present day, woody vines, which climb trees, by hooking themselves on by tendrils formed by the transformation of their inflorescences or of certain branches, and by enrolling their stem round the sustaining plant. Their maximum height may be 25 meters (say 80 feet) (Captain Chaltin), probably even greater; their trunk may attain a thickness of 15 centimetres (say 6 inches) in diameter, and even more (*L. comorensis* [Boj.], var. *florida*, K. Schum.); I have never seen trunks of that size, but I have examined, at Berlin, portions of vines having a diameter of 5 centimeters (2 inches)." I cannot, moreover, give a better idea of the appearance and manner of life of these vegetables, than by transcribing a passage of R. P. Merlon relative to the *L. comorensis* (Boj.), var. *florida*, K. Schum., which he calls the vegetable boa: "Trailing its trunk on the ground, stripped underneath, gliding across all the thorns, running with enormous bounds

over the footpaths of the deer, circumventing the rocks, shooting towards the large trees, which it inlaces, throwing its bridges of verdure and its dark assemblage of branches from one bank of the streams of water to the other, redescending to the ground further on, where it entangles itself in an inextricable network of roots, this peculiar and wild plant occupies immense regions in the mysterious forests of the interior."[1]

Stem.—The stem, of a brown or greyish colour, is generally covered with numerous lenticells. In the case of certain species (*L. comorensis* [Boj.], K. Schum., *L. senegalensis*, D. C.) the stems are completely glabrous, but in the majority brownish downs are present on the young branches (*L. Petersiana* [Kl.], Th. Dyer, *L. Lecomtei*, A. Dew., *L. Kirkii*, Th. Dyer, *L. parvifolia*, K. Schum., etc.), sometimes even on old branches (*L. tomentosa*, A. Dew., *L. bracteata*, A. Dew., etc.); perhaps down is still present on even some of the adult stems. Leafy branches start from the stem in greater or less number.

Leaves.—The leaves are opposite, petiolated, usually elliptical, sometimes almost rounded (certain forms of *L. Petersiana* [Kl.], K. Schum., some leaves of *L. madagascariensis* [Boj.], K. Schum.), sometimes oval or oboval, acute at the apex (*L. Petersiana* [Kl.], Th. Dyer, *L. parvifolia*, K. Schum., *L. Kirkii*, Th. Dyer, etc.), sometimes obtuse (*L. comorensis* [Boj.], *L. madagascariensis* [Boj.], K. Schum., *L senegalensis*, D. C., *L. lucida*, K. Schum.), or more or less rounded (*L. tomentosa*, A. Dew., *L. Thollonii*, A. Dew.), rather often prolonged into a long or short mucron, pointed or rounded [(*L. Lecomtei*, A. Dew., *L. Heudelotti*, D. C., *L. owariensis*, P. D. Beauv., etc.)]; the base is most frequently cuneiform [(*L. Kirkii*, Th. Dyer, *L. Petersiana* [Kl.], Th. Dyer, etc.)], sometimes more or less rounded [(*L. comorensis* [Boj.], K. Schum., *L. bracteata*, A. Dew., *L. Thollonii*, A. Dew., *L. Lecomtei*, A. Dew.)], rarely cordate [(*L. lucida*, K. Schum., *L. bracteata*, A. Dew.)]; the edges of the limb are often recurved towards the inferior surface; the latter is often dull and pale, whilst the upper surface is lustrous and deeper in tint. As a general rule, these leaves are coriaceous, sometimes glabrous [(*L. comorensis* [Boj.], var. *florida*, K. Schum., *L. madagascariensis* [Boj.], K. Schum., *L. senegalensis*, D. C., *L. Petersiana*, Th. Dyer, etc.)], sometimes downy; in the latter case the down is not commonly found, except on the veins, and almost exclusively on the under side; amongst the most downy we may cite *L. tomentosa*, A. Dew., *L. bracteata*, A. Dew., *L. Traunii*, Sadeb., and *L. Michelinii*, Benth.; on the upper surface only the mid-rib is downy, rarely some rare hairs are observed on the limb. In some species the edges of the leaf are ciliated, especially in *L. Kirkii*, Th. Dyer. The presence or absence of hairs would not appear to be very constant characteristics. The nervation is pinnate in all the species of the genus; a mid-rib is always present, glabrous or pubescent, generally making rather strong projectures on the inferior surface, crossed in grooves on the upper surface; in *L. madagascariensis* it is wide and not grooved on the upper surface; the secondary veins are inserted almost perpendicularly or more or less obliquely on the mid-rib. The latter are sometimes numerous, packed parallel one against the other (*L. madagascariensis* [Boj.], K. Schum.), at other times more distant (*L. comorensis* [Boj.], K. Schum.), often uniting towards the margin in such a manner as to form a hem, which is particularly marked in *L. madagascariensis*, K. Schum., *L. lucida*, K. Schum., *L. Traunii*, Sadeb., *L. Heudelotti*, D. C., etc. The leaves are always furnished with a *petiole*, sometimes

[1] The first notice of the *Landolphia* yielding indiarubber is by Col. (now Sir) J. A. Grant, in the appendix to *Speke's Journal* (p. 639), repeated in an elaborate account of his collections published in the Linnean Society's Transactions (xxix. 107). In this he says of *L. florida*, "A wood-climber, named M'hoonga (Kis), found at Madi, Derembe, in a shady spot by a rocky burn. Its trunk travelled like a boa-constrictor along the ground till it found a tree to climb up, and was twenty-five inches in circumference; ascending to the topmost branches, it threw down pendants of foliage and clusters of lily-white, scented flowers. The milk if rubbed upon the skin adheres like bird-lime and can scarcely be rubbed off . . . The Wahiao people make playing-balls from the juice, and consider its rubber to be the most adhesive known."

but slightly developed (*L. crassipes*, Radlk.), rarely longer than 15 millimetres; generally it is pitted, not swollen at the base, except in *L. crassipes*, Radlk., exceptionally a little enlarged at its point of insertion on the stem, as is observed in *L. madagascariensis* (Boj.), K. Schum.; it is often downy, glabrous in *L. comorensis* (Boj.), K. Schum., *L. madagascariensis* (Boj.),' K. Schum., and some others.

Flower.—The inflorescences are terminal or lateral, all constructed on the same type. They consist, in a more or less reduced state, of panicles, or, more scientifically, of corymbiform or thyrsiform cymes; they always comprise a peduncle which, sometimes sessile or almost sessile (*L. parvifolia*, K. Schum.), may attain in certain species (*L. Petersiana* [Kl.], K. Schum.) a considerable length, 16 centimetres (6¼ inches). This peduncle is continued by a rachis, on which secondary branches are inserted, to which sometimes some small branches, bearing a certain number of flowers, are attached. It may happen that the tertiary branches are awanting, and that the secondary and primary are greatly foreshortened, so as to simulate a kind of capitulum (*L. Thollonii*, A. Dew., *L. parvifolia*, K. Schum.). The rachis may be elongated so as to leave a rather considerable space between the secondary branches. The panicles of *L. Petersiana* (Kl.)., K. Schum., are produced in this way. These inflorescences are generally covered with brown down, or glabrous in *L. comorensis* (Boj.), K. Schum.

After flowering, the majority of the species, perhaps even the whole, elongate certain of their inflorescences, sometimes very greatly (*L. Petersiana* [Kl.], K. Schum., and *L. senegalensis*, D. C.), and transform them into tendrils, which in the end become lignified. The flowers are always hermaphrodite, constructed in a rather similar fashion in the different species. They include a calyx, rarely glabrous (*L. comorensis* [Boj.], K. Schum.), more frequently pubescent or covered with brown down, divided as far as or almost as far as its base into five lobes, accidentally into four lobes, often coriaceous, carinated (keel-shaped), lanceolate, or elliptical, more or less acute or obtuse at the apex. In *L. Kirkii*, Th. Dyer, the base of the divisions is rounded, slightly pedicillate. The length of the sepals hardly exceeds 8 millimetres in those species where they are largest in size (*L. bracteata*, A. Dew.); the most frequent size is 2 or 3 millimetres; the species with large flowers have generally very small calices. Thus the *L. madagascariensis* (Boj.), K. Schum., and the *L. comorensis* (Boj.), K. Schum., the corollæ of which measure 40 millimetres (say 1½ inches) and more in length, have calices of 1·5 to 2 millimetres. There are no glands or appendages in the interior of the calyx. The funnel-shaped corolla always consists of a tubular portion, dividing in its upper part into five almost equal petals, which before flowering are twisted to the left. Its total size, that is to say, from the base of the tube to the apex of the petals, varies between 5·5 to 60 millimetres (say from ⅕ to 2⅓ inches). The tube is rarely thin and glabrous (*L. comorensis* [Boj.], K. Schum.), more frequently hairy and coriaceous, narrow (1 to 3 millimetres), exhibiting either immediately above the calyx [(*L. Kirkii*, Th. Dyer, *L. Thollonii*, A. Dew., *L. parvifolia*, K. Schum.)], or throughout the whole extent of the inferior part [(*L. madagascariensis* [Boj.], K. Schum., *L. comorensis* [Boj.], K. Schum., *L. comorensis* [Boj.], var. *florida*, K. Schum., *L. Petersiana* [Kl.], Th. Dyer, etc.)], a more or less marked swelling. In *L. Lecomtei*, A. Dew., this swelling is a little above the middle. In fact, some species, the *L. Heudelotii*, D. C., for example, have an expanded tube throughout their whole length, only contracting underneath the petals. The length of the tube varies between 2 millimetres (*L. Kirkii*, Th. Dyer) and 25 to 26 millimetres (*L. comorensis* [Boj.], K. Schum., and its variety); its dimensions exceed in certain species those of the petals; in others they appear perceptibly equal; finally they are sometimes smaller. No appendages are found in the throat of the corolla in plants of this class. The petals are sometimes glabrous exteriorly (*L. comorensis* [Boj.], K. Schum.); more often they are ciliary on their edges; many species with small flowers have downy petals on the exterior; their form is generally lanceolate, oboval, or fusiform, more or less acute at the apex, sometimes slightly rounded. Their size, in certain species, *L.*

Kirkii, Th. Dyer, for example, is from 3 to 4 millimetres in length by 1·25 millimetres in width. In others, such as the *L. comorensis* (Boj.), K. Schum., and the *L. comorensis* (Boj.), var. *florida*, K. Schum., they reach as much as 40 millimetres in length by 6 to 10 millimetres in width. In the living state the flowers of the *Landolphia* are white (or yellowish), and exhale a very pronounced odour of jasmine; dry, their tint varies from brownish yellow to deep reddish brown. The *stamens*, to the number of five, are lodged in the swollen part of the tube of the corolla, and are consequently hidden; they are reduced to free anthers, in the form of arrows, prolonged into rather a long point at the apex, and attached by a very slender filament to the side of the tube. The *pistils* themselves are also very short; they comprise a globular ovary, glabrous or pubescent, especially at the base of the style, unilocular, containing two parietal placentas, on which are attached numerous small grains; the styles which they bear at the apex are, in the larger species, 5 or 6 millimetres; they are terminated by a fusiform stigma, pubescent, prolonged by a sort of double hanging beak. The flowers are intermingled with bracts, generally small and downy; the largest are found in *L. bracteata*, A. Dew.; they are two in number, very downy on the outside, situated at the base of each group of flowers. Their dimensions are, 6 millimetres in length by 3 millimetres in width.

Fruit.—The fruits are spherical or piriform bays, with a coriaceous envelope, which may in certain species reach the size of a cocoanut, often becoming reduced to the size of an orange, of an apricot, or still smaller fruit; their colour in the fresh state is yellow or brown; dry, it is black; their surface is glabrous, sometimes *pruineuse* (? prickly), covered with lenticells; inside the fruit are seeds, more or less numerous, which, according to what little is known of them, do not appear to have the same structure in all species. In fact, those of *L. comorensis* (Boj.), var. *florida*, K. Schum., bear two distinctly visible, wide, thin, foliaceous cotyledons, applied against one another, and surrounded by a horny albumen; those of *L. Kirkii*, Th. Dyer, exhibit a continuous albumen, without differentiated cotyledons and a very small embryo placed at the apex of this albumen. The integument of the seed is, in all the known species, surrounded by an acid, edible, pulpy layer, which results from hairs gorged with juice which cover its surface.

Geographical Distribution.—The genus *Landolphia* is peculiar to Africa; twenty-one species are known, spread between the 16° N. lat. and the 30° S. lat., that is to say, stopping on the north, where the desert of the Sahara commences, and penetrating neither into Nubia nor into Egypt. In the south, it would only appear to exist in the north of Cape Colony; it has not yet been, so far as I know, observed south of the Diamond Fields. The most widely distributed species are the *Landolphia comorensis* (Boj.), var. *florida*, K. Schum., and the *L. Petersiana* (Kl.), Th. Dyer, which are found throughout almost all Africa to as great an extent on the eastern as on the western coast. The following species are met with on the western coast:—*L. comorensis* (Boj.), K. Schum.; *L. comorensis* (Boj.), var. *florida*, K. Schum.; *L. Petersiana* (Kl.), Th. Dyer; *L. Petersiana*, var. *crassifolia*, K. Schum.; *L. Lecomtei*, A. Dew.; *L. lucida*, K. Schum.; *L. owariensis*, Pal. de Beauv.; *L. senegalensis*, D. C.; *L. Heudelotii*, D. C.; *L. Michelinii*, Benth.; *L. Traunii*, Sadeb.; *L. tomentosa*, A. Dew.; *L. parvifolia*, K. Schum.; *L. Manii*, Th. Dyer; *L. Thollonii*, A. Dew.

On the eastern coast the following have been signalised:—*L. comorensis* (Boj.), K. Schum.; *L. comorensis* (Boj.), var. *florida*, K. Schum.; *L. Petersiana* (Kl.), Th. Dyer; *L. Petersiana*, var. *crassifolia*, K. Schum.; *L. Kirkii*, Th. Dyer; *L. capensis*, Oliv.; *L. crassipes*, Radlk.; *L. madagascariensis* (Boj.), K. Schum.; *L. angustifolia*, K. Schum. The different *Landolphia*, so far as is known at present, are quite localised. A tabular list of the regions of Africa, with the species which grow there, will sufficiently show this to be the case.

Table II.—Distribution of the Various Species of Landolphia in the African Indiarubber Zone

Western Coast

Region.	Species.
Senegambia	*L. comorensis* (Boj.), var. *florida*, K. Schum. *L. Petersiana* (Kl.), K. Schum. *L. senegalensis*, D. C. *L. Heudelotii*, D. C. *L. Michelinii*, Benth. *L. Traunii*, Sadeb. *L. tomentosa*, A. Dew.
Foutah-Djallon	*L. comorensis* (Boj.), K. Schum. *L. Heudelotii*, D. C.
Gambia	*L. senegalensis*, D. C. *L. tomentosa* (Lep.), A. Dew.
Niger, Benin, Abbeokuta	*L. comorensis* (Boj.), var. *florida*, K. Schum. *L. owariensis*, Pal. de Beauv.
Calabar	*L. bracteata*, A. Dew. *L. Traunii*, Sadeb.

Region.	Species.
Cameroons, Togaland	*L. comorensis*, (Boj.) var. *florida*, K. Schum. *L. owariensis*, Pal. de Beauv. *L. Heudelotii*, D. C. *L. Manii*, Th. Dyer.
Corisco Bay	*L. Manii*, Th. Dyer.
Gaboon and French Congo	*L. comorensis* (Boj.), K. Schum. *L. comorensis* (Boj.), var. *florida*, K. Schum. *L. Petersiana* (Kl.), Th. Dyer. *L. Petersiana*, var. *crassifolia*, K. Schum. *L. Lecomtei*, A. Dew. *L. owariensis*, Pal. de Beauv. *L. Thollonii*, A Dew.
Congo Free State	*L. comorensis* (Boj.), K. Schum. *L. comorensis* (Boj.), var. *florida*, K. Schum. *L. Petersiana* (Kl.), Th. Dyer. *L. owariensis*, Pal. de Beauv. *L. lucida*, K. Schum.
Angola	*L. comorensis* (Boj.), var. *florida*, K. Schum. *L. Petersiana* (Kl.), Th. Dyer. *L. owariensis*, Pal. de Beauv. *L. parvifolia*, K. Schum.

Eastern Coast

Cape	*L. capensis*, Oliv.
Transvaal	*L. capensis*, Oliv.
Delagoa Bay	*L. Kirkii*, Th. Dyer. *L. Petersiana*, var. *crassifolia*, K. Schum.
Mozambique	*L. Kirkii*, Th. Dyer. *L. Petersiana* (Kl.), Th. Dyer. *L. comorensis* (Boj.), var. *florida*, K. Schum.
Madagascar	*L. madagascariensis* (Boj.), K. Schum. *L. crassipes*, Radlk.
Comores Isles . . .	*L. comorensis* (Boj.), K. Schum.
Dar-es-Salam . . .	*L. Kirkii*, Th. Dyer. *L. Petersiana* (Kl.), Th. Dyer.
Zanzibar	*L. Kirkii*, Th. Dyer. *L. Petersiana* (Kl.), K. Schum. *L. comorensis*, var. *florida*, K. Schum.
Usambara	*L. angustifolia*, K. Schum. *L. Kirkii*, Th. Dyer. *L. Petersiana* (Kl.), Th. Dyer. *L. comorensis* (Boj.), var. *florida*, K. Schum.
Djours	*L. Heudelotii*, D. C. *L. owariensis*, Pal. de Beauv. *L. comorensis* (Boj.), var. *florida*, K. Schum.
Bahr-el-Ghazal . . .	*L. Heudelotii*, D. C.

Morris classifies *Landolphia* according to the size of leaf and flower thus—

1. *Species with large flowers.—L. florida, L. madagascariensis, and L. Petersiana.*

2. *Species with small flowers and large leaves.—L. senegalensis, L. owariensis, and L. tomentosa.*

3. *Species with small flowers and small leaves.—L. Kirkii.*

Table III.—Classification of Landolphia, according to their Value as Rubber Producers

Good.	Doubtful.	Worthless.
L. Heudelotii, A. D. C.	*L. kilimandjarica*, Stapf.	*L. florida*, Benth.
L. Kirkii, B. Dyer.	*L. Buchananii*, Stapf.	*L. uganensis*.
L. Dawei, Stapf.	*L. Holzii*, Busse.	*L. subturbinata*, Stapf.
L. owariensis, Beauv.	*L. drovgmanansia*, de Wild.	
	L. Klaireii, Pierre.	
	L. reticulata, Halker.	
	L. Petersiana, Dyer.	
	L. Pierrei, Hua.	
	L. lucida, var. *Hispeda*, Hall.	

(6) *Funtumia elastica.*—This is a plant of recent importance (see pp. 84 *et seq.*).

(7) The *Urceolas*, genus of *Apocynaceæ*, consisting of six Malay vines, distinguished in the *Ecdysanthereæ* group by flowers with a non-glandular calyx; an areolar or globular valvate, subinduplicate, or more often slightly twisted corolla, the right edges of the lobes folding backwards on themselves; an entire or five-lobed disc. *Urceola elastica*, a climber with a trunk as thick as a man's body, has a soft, thick bark, may be tapped when three years old, and soon shoots up after being cut down. Borneo rubber is not the product of an *Urceola*, but of species of *Willughbeia* and *Leuconotis*. *Urceola* (Chavannesia) *esculenta*, Benth., a climbing plant with smooth branches and leaves, known locally as "Kyat-poung-hpo," is a troublesome weed in the teak forests of Burmah, but yields

FIG. 11.—*Funtumia elastica*, Stapf. Natural Order, *Apocynceæ*. The ire or Lagos rubber plant formerly known as Kicksia Africana. 1, Flowering branch, two-thirds natural size; 2, bud; 3, segment of calyx with glands at the base; 4, corolla cut open with style and stigma removed; 5, another front view; 6, pistil with disc, *d*; 7, a pair of follicles, fruit two-thirds natural size; 8, seed of transverse section of seed; *t*, testa, *a*, albumen, *c*, cavity. Nos. 2–6, 8 and 9, all enlarged.—(Kew Bulletin.)

caoutchouc of excellent quality. The plant is cultivated to some extent for the sake of its fruit, which finds a market as a substitute for tamarinds. It has been under experimental cultivation in Madras, but it was found to be slow of growth, and not regarded as of much promise as a rubber producer. Several species of this genus have been reported as yelding fair quantities of useful rubber. *Urceola esculenta*, Benth., in British Burmah and other parts of India, yields dry rubber with 75–80 per cent. of caoutchouc. *Urceola elastica*, Roxb., in Malaya; *Urceola acute acuminata*, Boer., in Borneo; and *Urceola Maingayi*, Hook, f., in Singapore and Borneo, are said to yield milk occasionally rich in caoutchouc. One species—yielding 25 grammes of rubber—*Urceola brachysepala*, Hook, f., thrives in Malaya, Borneo, and Java, and may be cultivated up to an altitude of 2300 feet (Jumelle).

(8) The *Hancornias.*—A genus of *Apocynaceæ-crotoneæ*, sub-tribe *Eucarissæ*, characterised by a quinque-partite corolla, with non-glandular lobes, arranged in a quincunx manner, in the *preinflorescence.* Corolla, hypocraterimorphous, with a narrow tube, hairy within, one at the level of the throat, surmounted by a limb with five linear lanceolate divisions. Five stamens, inserted in the middle of the tube of the corolla, with lanky filaments bearing linear anthers, acuminated, of the same length as the filaments; nectary absent. Ovary single, fusiform, and glabrous, divided into two dissepiments by a thick fleshy partition, surmounted by a filiform style, with an induced linear, conical, bilobed stigma. The ovules are numerous, amphitropous, inserted on each side of the partition walls. The fruit is a globular or pear-shaped bay, pulpy, latescent, unilocular by the abortion of one of the carpels, containing numerous ovoid and compressed seeds embedded in the pulp of the fruit, provided with a hard albumen and a central embryo, erect, with a very short radical and sub-oval cotyledons. The *Hancornias*, which yield Mangabeira rubber, are small latescent shrubs with opposite entire leaves, short petioles, and odoriferous flowers. The fruits of the *Hancornia speciosa* (Gom.) and of the *Hancornia pubescens* (Nees and Mart) are commonly known under the name of *Mangaba*, and are very much sought after by the natives.

(9) The *Alstonia* (C.) gives its name to the tribe of the *Alstoniæ*, of the family of the *Apocynaceæ.* Its regular, hermaphrodite flowers have a gamosepalous calyx with five divisions, quincocial in the bud, a gamopetalous corolla, hypocraterimorphous, with five lobes, in twisted inflorescence, an andrecium of five enclosed stamens, and a gynœcium analogous to those of the *Apocyneæ.* The fruit is composed of two narrow elongated follicles containing numerous flattened seeds, terminated at each extremity by a winged, ciliated membrane. Fine trees of northern Oceania and tropical Asia. Leaves opposite, and flowers united in spikes of cymes. The latex is as bitter as that of gentian. *Alstonias scholaris*, the *chatwan*, is a large evergreen tree, 60 feet high, found in the drier forests of India, but extending to Ceylon, Singapore and Penang, the Malay Archipelago, tropical Australia, Africa. It has large leathery leaves and greenish-white flowers, with very long and slender follicles. It has long been regarded as producing an inelastic rubber-like substance, but so far no use has been found for it. Dr. Ondaatje in 1884 sent from Ceylon a large sheet of a resinous substance got from the latex of *Alstonia scholaris.* He claimed it to be a good substitute for gutta percha, being plastic, acid resisting, soluble in chloroform, precipitated by alcohol. The substance had been prepared with care and pressed into sheets. No information was given as to quantity available or cost of production. The specimen is still in Kew Museum.

(10) *Chonemorpha* (G.).—Genus of *Apocynaceæ*, sub-tribe of *Euéchitideæ*, short, tubular, quinquefid calyx, furnished at its internal base with a glandular ring. The corolla subinfundibuliform, with a very short tube, and naked, tubular, elongated neck. The stamens are enclosed, with very short broad filaments, with anthers adherent to the stigma, and furnished with short appendices to the base of their lobes. The ovary, surrounded by a thick disc, entire, or scarcely five-lobed, has two distinct multiovular carpels, surmounted by a filiform style, split at its base, and presenting below its bifid summit a fleshy stigma, inferiorly dilated into an annular membrane. The fruit is composed of two triquètre follicles, the numerous seeds of which, at their extremity, thinned out into a spur, exhibit a crown of long hairs. The albumen is not abundant, and the cotyledons are thick, flat, and oblong, with a short radicle. They are pubescent, sarmentose, climbing shrubs, with opposite, wide, feathered-veined leaves and beautiful, large white flowers, uniting in branching cymes, loose, terminal, and sometimes pseudo-axillary. Some two or three species are known in the East Indies and Malay Archipelago, *Chonemorpha macrophylla*, a stout climbing shrub, found in moist forests of India, Ceylon, Malacca, Andaman Islands, Sumatra, Java. Value as rubber plant little known except that "it yields a considerable quantity of caoutchouc" (Parish, quoted by Kurz in *Forest Flora*, ii., 117).

(11) *Willughbeia.*—Much rubber hitherto ascribed to *Willughbeia* will have to be transferred to other species (Watt). That from *W. edulis* contains as much as 84·6 per cent. of resin and only 10·8 of caoutchouc.

(12) *Carpodinus* and *Clitandra.*—These plants secrete rubber by their stems and roots. They are better rubber-producing plants than the *Landolphia tholloni* of the same region. They grow rapidly on sandy ground, and cover the ground like couch-grass.

(13) *Ecdysanthera micrantha.*—A large climbing shrub of Darjeeling, Himalaya, thriving at an altitude of 3000–5000 feet.

Another plant, mentioned by Mr. Horne, is *Alstonia plumosa.* Of this there is a hairy form, with smaller leaves (*A. villosa*, Seemann). The large-leaved plant is known locally as "Drega quruquru." *Alstonia plumosa* is known in Viti Levu as "Sarua." It abounds in the forests, and, if arefully treated, might prove a useful rubber-producing plant. Mr. Jeske, the Commissioner for Colo North, states: "The leaves are large and glossy: the gum is obtained from the petiole or stalk. As

FIG. 12.—Plants producing the New Root Rubber from the Congo and Loando. *A*, *Carpodinus lanceolatus*, natural size, showing underground stem or rhizome from which the rubber is obtained; *B*, Top part of shoot of the same, one-sixth natural size; *C*, Single flower cut open on one side, three-fourths natural size; *D* and *E*, *Clitandra Henresguiana*, one-tenth natural size.—(Tropen pflanzer.)

soon as the leaf is broken a thick milky juice exudes, which when exposed to the heat of the sun for a little while congeals. It is then detached with a bit of bamboo or knife, and the different particles are pressed together into balls. That is the way it is produced when required as an article of commerce."

ASCLEPIADEÆ

The *Cynanchum* (L.)—(*Asclepiadeæ*, tribe *Cynanchæ*)—characterised by five partite, acutely divided calyx, containing five to ten glands within its basilar region. Corolla subrotate, deeply quinquefid, oblong or rounded lobes, contorted folds from right to left, membranous corona, in juxtaposition to staminal tube, cupuliform or annular at base, with five lanceolate or liguliform lobes, with small tongue or scale inside with denuded sinus, two-teethed, or presenting a small lobe. Stamens inserted at base of corolla, with connate filaments in very short tube. The antherous membrane bent from without inwards, each dissepiment containing a single pollen grain, ovoid, oblong, noncompressed, attached some distance below its

summit. Stigma, the central region of which is slightly convex, or in form of surbased cone. Follicles very thin, acuminated, light. Seeds bearded. Twining subshrubs, glabrous, or scarcely pubescent, opposite, cordiform, or hastate leaves, with small flowers arranged in umbelliform or racemiform cymes, situated at the level of a single axil; pedicels filiform.

FIG. 13.—Guayule Rubber—(*Parthenium Argentatum*). Natural order, *Compositæ*. The illustration shows natural growth of the wild plant and method of collection.

The *Periploca Græca* (L.)—(*Asclepiadaceæ*)—distinguished by granular, non massive pollen, glued, however, to a corpuscle, dilated at its extremity, corolla rotate, twisted, lined with a crown, with short, wide scales, generally prolonged into five awl-shaped ligules. Milky, twining plants, sometimes aphyllous.

The *Calotropis procera* (R. Br.)—(*Asclepidaceæ*)—with opposite decussate leaves, subsessile, embracing stem, obovate, superior surface smooth; inferior

surface covered with white woolly pubescence. Inflorescence in composite umbels, peduncles woolly; large, very pretty flowers, of a rose colour mixed with purple; calyx in five divisions; corolla campanulate with angular tube, limb with five segments, oblong, obtuse, revoluted, bent, from without inwards to the point. Corona, with five scales, adhering to staminal tube, rather fleshy, compressed laterally, prolonged in the back at base or towards middle into a tube, recurved upwards. Stamens with connate filaments in short tube; pollen grains solitary in each dissepiment, oboval, oblong, compressed, suspended from summit; stigma obscured pentagonal; follicles short, acuminated, with bearded seed.[1]

Cryptostegia grandiflora (R. Br.).—A handsome climbing plant, the "Pulay," with glossy leaves and pale purple flowers in large, terminal clusters, probably a native of Madagascar, but now naturalised in India and many parts of the Tropics, is said to yield good rubber. Rubber of fair quality, about 30 per cent. caoutchouc.

NATURAL ORDER *Compositæ*. — If this natural order comprises a great number of genera and species distributed over all regions of the globe, yet it comprises but very few species capable of being cultivated for indiarubber; but lately the source of guayule rubber in Mexico has been identified as *Parthenum Argentatum* (*Asa Gray*) (see Fig. 13).

NATURAL ORDER *Lobeliaceæ*.—*Syphocampylus*, a South American tropical species, is said to yield commercial rubber in Columbia and Ecuador.

According to Jumelle, *Sonchus Oleraceus* (L.) yields valuable rubber. Colorado rubber is said to be derived from a species of Hymenoxys.

[1] This genus is retained here as a rubber-yielding plant, as it was so placed by the authors. But its product is described as a *pseudo gutta* by Hooper.—J. G. M.

CHAPTER II

METHODS OF OBTAINING THE LATEX—METHODS OF PREPARING RAW OR CRUDE INDIARUBBER

Beyond the sphere of the general causes (see Chapter I.) which influence in so many different ways the richness of the latescent juice, there is another and quite a special influence—independent altogether of the predetermining influences of natural agents—which depends solely on the intelligence of the operator, namely, the methods adopted for collecting the latex, as well as the processes employed to extract the indiarubber from the harvested juice.

Wright points out that the "commercial possibilities and the ultimate success of several species are determined by the particular type of laticiferous tissue which each contains; each type (he insists) requires to be dealt with in a particular manner: it is very dangerous to adopt the same methods of tapping for all species. The principles of paring and pricking the primary and renewed cortex should be studied more seriously and intelligently than they appear to be at the present time. When one considers the great difference in the nature, mode of origin, and development of the laticifers in various plants, there is every reason for suggesting that each species should be tapped on a particular system in order to take advantage of the peculiarities of each type. These remarks are made because there is a tendency among responsible persons to recommend or adopt for their *Castilloa*, *Manihot*, *Funtumia*, *Landolphia*, and *Ficus* plants, the system of tapping which has been found to be so successful with *Hevea braziliensis*. From a study of the laticiferous system of our prominent plants, I am convinced that in certain instances the old, native, and apparently wasteful, methods adopted in the extraction of latex are probably as good as, and even better than, many which have been evolved. The laticiferous system in several of our important species occurs in the cortex of the stem, branches, roots, and in the leaves, flowers, and fruits. In some species the laticifers appear to be best developed in the root, and the extraction of latex is only considered in relation to that part; in other species there appears to be a better development in the stem, and in a few others the flowers or young twigs show conspicuous developments. Generally, these structures and the latex appear in the embryo and remain until the death of the plant; in some cases, however, the laticifers are not obvious except in plants of some years' growth. Sometimes they are absolutely restricted to stem and roots, the leaves and flowers never being in possession of such structures; in a few cases they appear in the young tissues, and then gradually die and disappear. There are three types of laticiferous systems, the components of which are scattered freely throughout the cortex in the stem; they may, according to their age and the condition of the plant, be partially or wholly filled with latex. When the cortex is incised the latex escapes, the quantity thus issuing depending largely upon the structural relations of the laticifers and the moisture conditions. A given incision allows the latex to issue only from a local area, dependent in extent upon the nature of the laticiferous system being tapped; generally several, and sometimes a very large number of, incisions may be made on the basal part of the stem."

Perkin observes that the latex from the thin stems of *Urceola elastica*, such as bear the leaves or have recently shed them, forms a sticky substance when moulded between the fingers and thumb. The plant resembles *Castilloa* in this

respect. The latex both from the pith and from the cortex of the young stem is sticky, hence it looks as if the true caoutchouc is only formed in the secondary bast.

Influence of (a) *climate*, (b) *altitude, and* (c) *soil.*—The climate, the altitude, as well as the soil, or rather these three factors taken together, are not without a certain importance, from the point of view of the quantity and quality of the latex. For altitude in Ceylon where *Hevea* may be grown, see Table XV.

Climate and altitude.—Although generally the culture of indiarubber can only be remunerative in the tropical zone, where a temperature reigns which never falls below 20° C. (say 68° F.), and never goes beyond 42° C. (say 107·6° F.), with an average rainfall of 2·06 metres (say 80 inches), even in the zone confined between the 30° of N. lat. and the 30° of S. lat., there exists so many variations in regard to heat, moisture, as well as altitude, that a certain species of plant may prosper in Brazil, without its being capable of being acclimatised in India. These assertions are amply confirmed in the chapters more especially devoted to acclimatisation and rational culture.

Methods of obtaining the Latex.—The latex is obtained by making incisions on the indiarubber tree: this operation seems a very simple one, yet it requires certain precautions, in view of the immediate industrial yield, but more especially in regard to the preservation and reproduction of the indiarubber trees. An untimely operation may destroy the end in view: the collection of the utmost quantity and the best quality, but, at the same time, the preservation of the harvests of the future.

Three methods are adopted for obtaining the latex:—1. The felling of the trees. 2. Bleeding by puncture or incision—"tapping." 3. Drying the root with subsequent maceration in water.

1. *Felling: an operation to be condemned.*—Felling the tree is an expeditious method, but is in general irrational and barbarous; it meets immediate wants, but does so only once. Nature, after many long years—a prolonged period of gestation—has placed at the disposal of man a working and producing tool, and with a single blow of the axe all this weary preparation is annihilated, and it once more requires another long lapse of time to repair what the improvidence, the thoughtlessness, the indolence, coupled with the greed of the collector, has destroyed. Felling is still carried on in Africa, in Asia, and more especially in the Indian Archipelago, where until recently it was the only method adopted in obtaining Borneo indiarubber; it is therefore, undeniably, to be condemned, except in perhaps two exceptional cases.

Exceptional cases in which felling may be justified.—(a) *Where tree, once bled, dies.*—In the case where, as is stated by the *gummeros* of Peru, the indiarubber tree on which they operate (*Hancornia speciosa*), once incised, even slightly, is inevitably killed by that single incision. Insects attack the bark and the tree, on the spot incised, and the tree soon dies. But if the tree be cut down close to the ground, sprouts, the growth of which is very rapid, spring up from the stump, new trees rise up in a cluster, and, after a few years, for one tree felled a whole group is reproduced. As the trees are very abundant, and as the activity of the collector is sufficiently exercised by operating on trees of full vigour, and also owing to a quasi-tacit agreement, only trees of more than a metre (3·28 feet) in diameter at the base are operated on, it would appear evident that this method of obtaining the latex has something rational in it. But beyond the fact that clusters of trees from the same stump have but little allurement, it is difficult to understand how the incised tree perishes in Peru, and continues to thrive in Ceara, in Ceylon, and on the Congo. Can future explorers and naturalists enlighten us on that point? Till then, the excellence of the native process is not demonstrated, and a better one can no doubt be elaborated.

(b) *For thinning or clearing purposes.*—There is a second case where felling may be justified: this is, when it is desired more especially to realise virgin forests—for example, those of Central Africa. An inextricable thicket, where the operator could not otherwise penetrate nor move about, can then be advantageously

cleared; moreover, felling admits air and light, so necessary for active growth, and if the operation be performed with intelligence and in a methodical manner there is nothing irrational in it. The essential thing is to make the native understand the point at which his work of destruction should stop. It is a delicate matter, difficult to settle.

2. *Bleeding by incision or puncture—"tapping."*—This is an infinitely more rational method; if performed methodically and carefully, so as not to injure the tree nor the quality of the rubber to be extracted from it. Brazil, and more especially the basin of the Amazon and its tributaries, is the country which has produced the indiarubber which is held in highest repute, so far as purity and quality are concerned. It is also in that country that tapping would appear to have been first practised in the most methodical way. It is therefore preferable to describe the process practised in that country, show its advantages, and quote it as an example each time that it may be compatible with the country and the plants operated upon.

The arrocho system of tapping.—The most primitive process of tapping known in Brazil under the name of *arrocho*, consisted in binding the *Hevea* with an obliquely adjusted rope, the tied knot being in the upper part. Above this ligature, tightened at the bottom, numerous incisions were made. The sap flowed, descended vertically, then meeting the rope, followed the small gutter which the rope formed with the tree, and at last arrived at the lower point, below which was a receptacle. This process damaged the trees to a very great extent, the *seringueiros* did not always take the trouble to remove the ropes, and the *Heveas*, strangled at their base, soon perished. Moreover, the latex, making a long journey down the tree, brought, in its train, mosses, wooden débris, and other impurities, afterwards found in the rubber. The incision was made with a butcher's knife, a pruning hook, or a cutlass, and penetrated more or less deeply into the trunk; and, where the tree was not mortally wounded, it was either insufficiently tapped, and did not yield sufficient latex, or too deeply, and thus facilitated the addition to the latescent juice of other juices more or less prejudicial to the purity of the rubber, and, above all, to its after-preservation. This process has been almost completely abandoned.

The present method of bleeding or tapping rubber trees in Brazil.—Tapping as now practised in the lower valley of the Amazon, is better understood and more rational; all writers on rubber have more or less completely described it. Carrey and Chapel give the most intelligible and the most methodical description. The *seringueiro* starts work at daybreak, *i.e.* about five o'clock in the morning. If the *estrada* (100 to 150 *Heveas*) which he is going to operate upon be rather far away from his hut, he has taken care to bring thither the previous night the tools required for his work. The first of these is the *machado*, a small hatchet with a short handle, the blade of which is only 3 centimetres (say $1\frac{1}{6}$ inch) wide, with a sharp cutting edge of about 5 milimetres (say $\frac{1}{5}$ of an inch), the bucket, and the *tigelinhas*, small white iron goblets. The *seringueiro*, or *cauchero*, is generally accompanied by his family or by one or more assistants; it is but rarely that he operates single-handed—a condition contrary to profitable working. After having previously well cleaned the outside surface of the tree to be incised, and removed the rubbish from around the foot of the tree, he commences to tap the tree. With a single straight cut of the hatchet he incises the bark so far that the latex flows, but without the wound mutilating the tree. He strikes the same trunk in a dozen places, taking care that his tool does not penetrate more than a few centimetres, according to the tree upon which he is operating. The shape of the *machado*, due to the sound practical sense of the North Americans, is, moreover, well chosen to attain the object in view, and it is with justice that E. Carrey remarks that "this small hatchet has saved more *Heveas* from destruction than all the protective laws of the Brazilian Assemblies. Since the time that the collectors of the Amazon adopted this tool, which only makes uniform, narrow, and easily executed incisions, the greater number of them have given up the use of those tools with which, in every sense of the word, they used to martyr the trunks of the *Heveas*.

Some collectors make their incisions in the form of a V, others make cuts along curved lines, at a distance of about 20 centimetres or 8 inches the one from the other. Finally, a great number are content to make vertical incisions, striking as high up the tree as the arm can reach, and repeating the blows down to the ground.

We insist greatly on a regular vertical incision; the *seringueiro* should never deviate from it. Experience has demonstrated that a tree incised in an irregular manner continues to yield its annual quota for the first and the second years following, but by the third year the milk begins to decrease, and soon dries up completely.

Repeated careful incisions, however, do not affect the tree. Numerous *Heveas* may be seen riddled with scars to such an extent that not a spot remains as large as the hand which has not been tapped, and in spite of these repeated assaults the tree retains its flourishing appearance. A tree 4 to 8 feet in circumference at its base can very well stand ten to twenty incisions every two or three days at the most. A daily incision would give an unremunerative yield.

FIG. 14.—Hatchet (*machete*, *machado*) used in tapping wild indiarubber trees in Brazil.

The *estrada* of 150 trees is generally divided by the *seringueiros* into three divisions, each of which is operated on every three days. If the *estrada* be smaller, 100 trees, the operation is repeated every two days. The whole season comprises in all twenty tappings per tree per annum; by going beyond that, the tree would be too much enfeebled and next year's yield compromised. One man, with his equipment, generally works the whole *estrada*; but this number is not fixed; all depends on the activity of the collector and on the proximity of the trees to each other. An essential condition is not to have to walk a long way from a tree which has been operated upon to one about to be similarly treated.

Period or season of collection.—The collection of the latex may be made at any season of the year, but it generally takes place in the period between the end of August and the first of January. Beyond this season the yield is not remunerative.

Hour at which trees are tapped.—Generally operations commence at daybreak; the trees, refreshed by the nocturnal breezes, bleed more profusely than at any other hour of the day. In some localities, however, the *seringueiro* prefers to make his incisions at dusk and to collect the first thing in the morning.

Height of the incision.—Tapping is practised to the extent of the sweep of a man's arm, about 0·3 to 1·8 metre (say 1 to 6 feet) above the ground. When the incisions have been made, the operator fixes *tigelinhas* below, and makes them adhere to the trunk by means of a little plastic clay, provided beforehand.

FIG. 15. — *Tigelinha*, cup used for collecting latex in Brazil.

Yield and duration of the flow.—Each regular incision with the hatchet distils its latex, drop by drop, from one to three hours, so as to yield 3 centilitres (rather more than 1 oz.) of milk. This quantity is not absolute, and may vary, according as the tree is in full vigour or in its decline. The yield differs, moreover, according to the year. The prolonged duration of the rains or excessive drought influences the flow of the latescent juice, in the same way as the situation of the incision, whether it be in the sun or in the shade, may determine a more or less abundant flow. This, to a certain extent, explains the preference of certain Indians for the nocturnal incisions of which we have just spoken. But those stormy rains which occur almost daily, and which have such a prejudicial effect on the quality of the latex collected, do not occur during the night, and this, again, is a further reason for the preference of the collector for the hour which he selects.

Influence of the phase of the moon on the secretion.—The native asserts that the flow is more abundant at full moon than at any other time. We do not know to what extent this assertion may be founded on fact; old folk often furnish very curious facts, based almost always on meteorological and telluric observations; science has often explained and almost always accepted them.

Yield of an estrada.—An *estrada* of 150 trees may on an average yield by tappings 52 litres (say $11\frac{1}{2}$ gallons) per incision, say 36 kilogrammes (80 lb. of

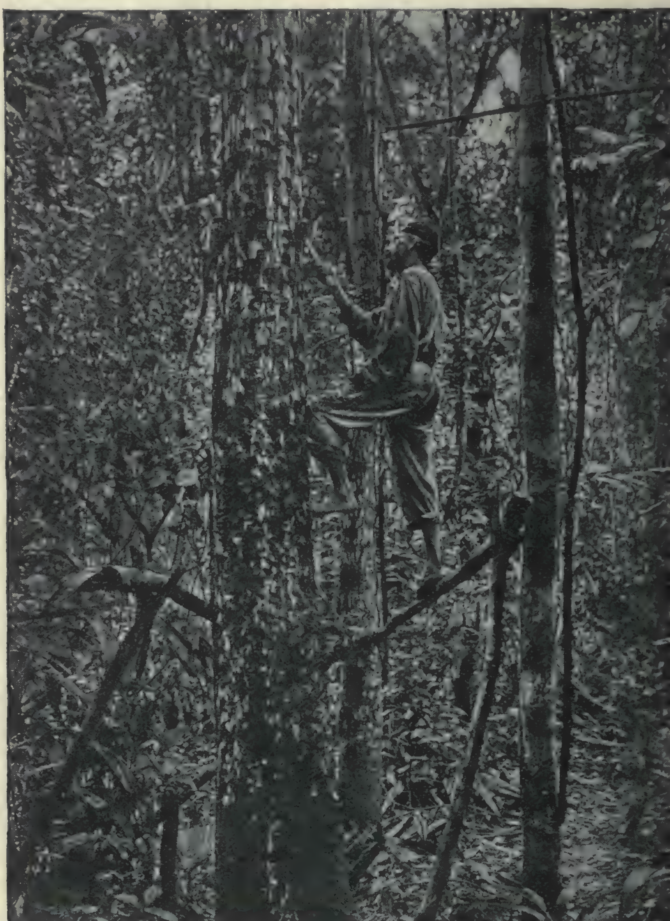


FIG. 16.—*Seringueiro* using an improvised ladder to tap the para indiarubber (*Hevea brasiliensis*).

raw indiarubber), which, at the average price of 5 francs the kilogramme (say 1s. 10d. per lb.), gives a return of 180 francs (£7, 4s.). It being given that twenty incisions are made annually, the season will produce a gross revenue of 3600 francs (£144).

The tapping methods of the Upper Amazon.—The methods of tapping in the Upper Amazon are almost identical with the preceding, except that the tools are more rudimentary, and the care taken in the management of the trees is not so well observed. The collector does not encumber himself with much baggage as he penetrates deeper and deeper into solitude. A calabash serves as a bucket, a

shell as a *tigelinha*, and the American hatchet gives place to the old wide-bent iron axe so deadly to indiarubber trees.

Other South American methods.—Almost without exception, the method of tapping is the same throughout the whole of South America; the arrangement, extent, and depth of the incisions are not always identical, the manner of collecting the secreted juice differs, but the principle is always the same.

Central American methods.—In Central America, where the principal indiarubber-yielding tree is of quite a different nature (*Castilloa elastica*), incision properly so called is often replaced by puncture, a smaller wound made by a hatchet of still more infinitesimal dimensions than that of the *machado*. In Mexico, says Wright, the natives seem to believe in the tapping of the higher parts of the Castilloa tree. In some parts of Mexico even Europeans appear to have recourse to large unwieldy kinds with which a heavy blow may be inflicted.

African processes.—In Africa, the methods of incision almost always differ from one locality to another, but until lately they have always been carried on in a very imperfect and irrational manner. But now Colonial Governments are educating the natives in rubber arboriculture. The product, which from its very nature is often, to a certain extent, inferior to South American rubber, and especially to that of Amazonia, loses still further in value by admixture with a foreign resin produced by too deep an incision. This resin very often brings about the decomposition of the caoutchouc.

Asiatic methods.—In Asia, and principally in those localities where the indiarubber is extracted from the different varieties of *Ficus*, the incisions are made on the lower part of the trunk and on the roots rising out of the ground; its form is elliptical, and it penetrates as far as the liber; it is 150 to 450 centimetres long and 73 centimeters deep.[1] The yield in latex varies with the season. The milky juice is not very abundant from February to March, but as its richness in rubber is considerable, therefore working is then most profitable. It is almost the same in August, a time at which the latex gives a yield of 30 per cent., but which diminishes as far as 10 per cent. during the other months.

3. *Oceanic methods.*—In Oceania, Asiatic methods are partially followed, when similar indiarubber trees are tapped; or the primitive process of felling, when the want of authority, coupled with short-sightedness or indolence of the local powers, leaves the natives to their own initiative. Their inconsiderate ravages are principally inflicted on the *Urceola elastica*, a plant which often attains a diameter equal to that of the human body. The shrub is broken up into pieces of 0·125 metre (say 5 inches) to 0·8 metre (say 31 inches), which are placed above large receptacles, intended to collect the juice which drops from them. If the exudation show signs of slackenings, or does not go on as the collector thinks it should, the flow is stimulated by the heat of a few kindled twigs.

Urceola esculenta.—As far as it is concerned, the methodical tapping as it ought to be performed consists in making, in the body of the plant, a V-shaped incision of 1 to 2 centimetres (from $\frac{2}{5}$ to $\frac{4}{5}$ of an inch in height by 3 to 4 centimetres, say $1\frac{1}{8}$ to $1\frac{1}{2}$ inches, in depth). These cuts ought to go right through the bark, but stop short at contact with the wood.

The microscopical structure of Urceola elastica.—The microscopical examination of the fragments of bark found in the mass amply show the necessity of this method; in fact we meet, below the suber, *su.*, which forms the external limits—(1) A thick, sclerenchymatous layer, C.S., consisting of a dozen rows of cells in radial lines; (2) an abundant parenchyma, *p.c.*, showing here and there masses of sclerenchymatous cells, c.s; (3) finally, an entirely soft liber, *li.*, very voluminous, which in itself alone constitutes one-half of the thickness of the bark, very rich in laticiferous tissue, especially in the young parts. The incisions ought therefore to penetrate as far as the cambium, so as to affect all the laticiferous vessels, and thus ensure the largest yield.

[1] Millimetres are evidently meant, say 6 to 18 inches long by 3 inches in depth.—Tr.

Summary.—Such are, sketched rapidly, the different processes in use for obtaining the latex. The influence which they exert on the preservation of the rubber-producing plants need not be dwelt upon further. The great importance of working rationally to secure this end is obvious. The same remark applies to the quantity of latex to be obtained, and to the yield of the latter in rubber. But the method of tapping nevertheless exerts a very important influence on the quality of the rubber extracted from the latex, and more especially on its keeping properties in the crude state. Too large, too deep, an incision may reach the liber, expose it too much, and impoverish the plant, if it does not cause it to die; it may, moreover, allow certain juices, from the interior of the plant, to mingle with the latex at the exit of the wound, and so alter its natural purity, and even affect eventually its proximate chemical constitution, converting it into a body of different chemical composition. But this influence is most deleterious when the latex has been obtained by felling. The milk is then forcibly mixed with

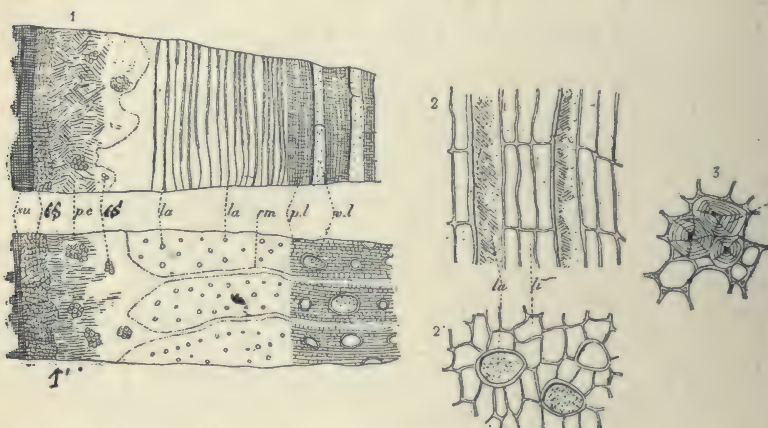


FIG. 17.—*Urceola elastica.*—1. Longitudinal and transverse sections—*su.*, suber; *p.c.*, cortical parenchyma; *c.s.*, sclerose cells; *la.*, laticiferous cells; *r.m.*, medullary rays; *p.l.*, ligneous parenchyma; *v.l.*, large ligneous vessels filled with latex. 2. Details of laticiferous vessels in the traverse and longitudinal section in the bark; *la.*, laticiferous vessels; *li.*, liber. 3. Details of the sclerose cells; *c.s.*, sclerose cells.

the other secretions which the plant may yield, whether saccharine, amylaceous, proteic, tannic, or resinous; and according to what these juices may be they will have a more or less injurious influence on the industrial rubber, and the qualities which commerce exacts from it. It will readily be seen that the French and American methods of obtaining oleoresin from the pine with their deep incisions to reach the new wood in which the resiniferous vessels occur are not adapted for indiarubber.

Methods of preparing commercial indiarubber from the juice.—Preliminary considerations.—This part of the authors' work is important, but at the same time the most delicate, and it is not without some hesitation that they enter upon it. All authorities acknowledge that rubber-extraction processes are in general defective, and considerably injure the marketable quality of the product, all of which has the effect of restricting the use of the latter. But technical literature is too often content to point out the evil without going deeply into the causes in a methodical manner, and without indicating any possible remedy.

Bobet's method for improving the coagulation processes.—"It would be advantageous to improve the processes of coagulation adopted in French colonies, and to do so it would be necessary to study the nature and properties of the latex,

and then to make some experiments on coagulation, so as to decide upon the best method to follow. On the supposition that these experiments could not be made on the spot, the local colonial officials could easily get them done in the mother country (neither willing hands nor talents would be found wanting), but it would be desirable to provide samples and the following data:—

"(1) *Necessary data for improvement of present processes.—Sample of rubber as now made.*—Send (*a*) sample of rubber as now collected; (*b*) indicate, if possible, the process adopted by the natives for extracting and coagulating the milky juice. (2) *Sample of specially prepared juice.*—Send a certain quantity of latex as it flows from the tree, when incised. So that this milk does not alter during the voyage, add a small quantity of ammonia to it, and enclose the mixture in a bottle or other hermetically sealed vessel. (3) *Botanical samples and other data.*—Furnish leaves, flowers, fruit, and seeds of the tree from which the milk has been extracted; indicate, if possible, the name of the tree and species to which it belongs; and state season during which the samples were collected. *Deductions to be drawn from above data.*—By means of such data it would be possible to decide upon the process desirable to adopt in collecting and coagulating the latex under the most favourable conditions. This acquired knowledge afterwards diffused by the government of the colony, would render the greatest of service to the natives, and to the colony itself, for it would impart to certain kinds a far higher value than what they now possess. Owing to the enormous number of rubber trees growing in equatorial Africa, the rubber trade of those countries, and particularly in French colonies, is destined to assume the greatest developments, *but provided always that the indiarubber exported be of the best quality only. In that case alone will the demand increase; and the settlements established on the coasts, finding an assured outlet, would be disposed to give a higher price for the rubber brought by the natives, and thus stimulate their zeal.*" Bobet's proposals, if carried out, would be a great step in advance in the improvement of the raw rubber. But this would not be enough, if, in face of these instructions, a methodical and critical comparison were not made of the processes now in use for the coagulation of the latex and the preparation of the marketable rubber.[1]

Collins' and Hœhnel's researches.—James Collins in Great Britain, Dr. F. de Hœhnel in Germany, and Dittmar in Austria, have partially taken the matter in hand. Taking advantage of their labours and experience, an endeavour will be made to investigate the subject as completely as possible.

Outlines of method of studying coagulation.—After outlining the methodical classification of the processes of coagulation generally used, each of these in its details, so as to draw rational conclusions from it; as well as the results which may be expected from them in regard to the quality of the marketable product, incidentally copious extracts will be made from a remarkable work by M. J. Morellet.

Influence of different methods of coagulation on rubbers from the same source.—Whether the latex be obtained by felling or by tapping, it does not yield the rubber in suspension until it has been coagulated, a process which may vary, from one country to another, and even in different districts of the same province, and from one bank of a river to that on the other side. It is not, therefore, rare for samples of rubber from the same country and the same plants to be of quite different qualities according to the method of coagulation adopted.

Classification of coagulation processes.—But these diverse processes may be classified into four groups, which may be further subdivided into sub-groups with some affinity to each other. The following is a table of methods of coagulation now in use, with their subdivisions, and the country in which each process is or has been formerly applied.

[1] The different Colonial Governments have now experts on the spot in all countries with rubber plantations, whose duties, *inter alia*, are to instruct natives how to collect and coagulate rubber.

TABLE IV.—CLASSIFICATION OF THE DIFFERENT METHODS OF COAGULATION OF THE INDIARUBBER LATEX.

Process.			Locality.
1. By heat.	α. Artificial heat.	I. Dry heat or smoking.	Amazonia, New Caledonia.
		II. Moist heat.	Mexico, Central America.
	β. Natural heat.	I. Absorption of the serum by the soil.	Angola.
		II. Absorption of the serum by the human body.	Congo, Angola.
		III. Evaporation on flat surfaces.	Ceara, Angola.
2. By creaming.	γ. Creaming after doubling its volume with water.		Bahia.
	δ. Creaming after standing, addition of four to five times its volume of water, drawing off the liquor, washing, and pressing.		Bahia, Congo.
3. By selection.	ε. Chemical selection by mineral reagents.		Matto Grosso, Pernambuco. Maranaho.
	ι. ,,	vegetable ,,	Peru, Guatemala, Nicaragua, Gambia, Madagascar, Casamanza.
4. By natural and artificial heat and chemical reaction combined.			Gambia, Senegal, Mozambique.
5. By churning or by centrifugal motion.			

To this table of methods there is added in No. 5 a churning process proposed by M. Rousseau, a process which is dealt with below.

Process in which the latex is coagulated by dry artificial heat or smoking—Where and on what rubbers practised.—This process is adopted in Amazonia to obtain Para rubber, the most famous species of caoutchouc, as regards purity, nervousness, and elasticity. It is also adopted in many other localities, from Brazil to Venezuela, in the Guianas, and is especially used in extraction of rubber from the latex of the *Heveas* and the *Micandras.* Until the new order of things, this process is the best of all those hitherto employed. It will be necessary to study it with care in its most minor details, because, although certain peculiarities may appear useless at first sight, they may really be important.

Collection of the latex—Preliminary treatment.—The tapping finished, the collector, or one of his assistants, provided with a bucket or a large cuya calabash, surrounded with an open meshed net and furnished with a plaited cord, which serves as a handle, detaches the *tigelinhas* or goblets, empties them into his collecting dish, and replaces them. He then leaves the tree, the latex of which he has just collected, but not without having minutely inspected the incisions, the lips of which are often obstructed by a pellicle of latex coagulated by natural heat—a pellicle which stops the further flow of the milky juice. If need be, he pulls off this pellicle, which he places on one side, on the rim of his dish, refreshes the wound, and then passes on to a second and a third tree to repeat the same process until the bucket is sufficiently full. If the hut of the *seringueiro* be close to the *estrada*, the latex collected is simply poured as it is into the collecting bucket without any precaution. But if the distance to be traversed between the *estrada* and the hut be rather far, the *cauchero*

FIG. 18.—Calabash in which latex is collected.

takes the precaution of adding about 3 per cent. of liquid ammonia to the latex. He thus prevents any coagulation which might occur, especially if the journey was made in the heat of the noonday sun. When enough has been collected, the preparation—properly so called—is proceeded with, namely, *smoking*.

Smoking the latex.—The workman, having previously cleared away the herbs, brushwood, and leaves, arranges his *fumeiro* over a hearth dug out of the ground. The *fumeiro* is a baked earthen furnace surmounted by a short conical pipe called a bouillon, of a rather narrow diameter, so as not to allow the fumes to spread too far afield. He fills the hearth with previously collected branches and applies a light.[1]

Fig. 18A.—*Fumeiro* or furnace for smoking rubber.

Fuel.—As soon as the smoke disengaged is sufficiently dense and thick, a point which the Indian ascertains by passing his hand into it, the *seringueiro* throws into the fire some previously provided palm nuts collected in the vicinity. Then some more wood and nuts alternately. The latter are dropped into the mouth of the jar until within 4 inches of the top. These nuts are the fruits of the *Urucury* or *Uaussu* palm tree (*Attalea excelsa* and *Manicaria saxifera*), which are also known in some localities under the name of *Carosses de Rocouri*. In default of these the fruit of the *Maximiliana regia* is used. Care is taken to use a proportional quantity of wood with the nuts. It is only in the Lower Amazon—that is, in the country where the preparation of natural rubber is the most skilfully conducted—that these nuts are used. Everywhere else the twigs of shrubs which are within reach of the hand are used in smoking.

As soon as the smoke is given off abundantly from the bouillon, the *cauchero* seizes the *mould* or *palette*, a wooden instrument having the appearance of a washer-woman's beetle,[2] but the handle of which varies in length from about 3 to 6 feet. He exposes the wide flattened end of this mould to the smoke for a minute, or moistens it with water charged with soft clay, to prevent the rubber from adhering to it, and then dips it into the bucket filled with latex, which lies close at hand, as near to the *fumeiro* as possible.

Fig. 18B.—Mould used in "smoking" the latex.

After holding the mould on edge for a sufficient length of time to allow it to drain sufficiently, the *cauchero* quickly places the mould, to which a slight coating of latex adheres, in the smoke, the flat side downwards, about 2 inches above the mouth of the jar, and makes a motion with it as if he were describing the form of a cipher, so that the current of smoke may be uniformly distributed over it. The other side of the mould is then treated in the same way. The two faces of the mould are thus equally smoked. Under the action of the heat and smoke, the latex is coagulated almost instantaneously, and assumes a yellow tinge; the mother liquor, which is exuded profusely, evaporates, leaving on the mould a first layer, which, though feeling firm to the touch, is soft and juicy like freshly coagulated milk. When the operator considers the coagulation sufficient and uniform, he again dips the mould in the bucket and repeats his continuous

[1] The authors' account of this operation is rather vague. The *fumeiro* is a bottomless jar 18 inches in height, 7 inches diameter at base, and narrowing at the mouth to 2 inches. Larger jars are used where a master employs a number of men. The *fumeiro* is set on three small stones which raise it above the floor, thus creating a certain amount of draught, which causes the smoke to rise with some force and regularity—Tr.

[2] The mould has been more aptly compared to the paddle of a canoe, and, as a matter of fact, this is the implement most frequently used on the Amazon for a large quantity of milk, yielding bulky masses of rubber. In such cases the mould is occasionally slung to the roof to lessen the fatigue of working (see Fig. 19).—Tr.

to-and-fro movements from the bucket to the *fumeiro* and from the *fumeiro* to the bucket, until the desired thickness has been attained, which is the case in the Lower Amazon, when the cake formed is the size of a military loaf and weighs about 5 kilogrammes (say 11 lbs.). He now frees his tool by splitting the block in the direction of its axis, in the upper part, with the point of a previously moistened knife, and recommences the making of a fresh block until the store of latex collected is exhausted. A workman can so prepare $2\frac{1}{2}$ to 3 kilos. (say $5\frac{5}{8}$ to $6\frac{3}{4}$ lb.) of rubber in an hour. The blocks so split, known in commerce as biscuits, are

FIG. 19.—Smoking Para rubber.

still moist. To dry them, the workman places them at sunset on the branches of the trees close at hand, and repeats this operation until they are perfectly dry, which takes several days. So prepared, the biscuits are marketed *Para fin.* Formerly Para rubber came to the European market in the shape of animals and little figures. The biscuit form is now dominant.

The characteristic properties of Para rubber due to "smoking" process.—The most onerous part of this method of coagulation is the smoking, which is the essence of the process which gives to Para rubber that universal, well-deserved reputation which it enjoys on our markets and in our factories. The following is the composi-

tion of the fresh latex used in the preparation of Para indiarubber. This information is necessary for the perfect understanding of the economy of the above process for obtaining rubber from the latex extracted from *Heveas* and *Micandras*.

TABLE V.—ANALYSIS OF THE LATEX USED IN PREPARING PARA INDIARUBBER.

	Per cent.
Indiarubber	32·0
Putrescible organic matter and mineral matter . .	12·0
Water	55 to 56·0
Ammonia . . . . (small quantities up to 3 per cent. of which are added to the liquid)	traces.
Resinous bodies	traces.
	100·0

Natural peculiarities of Para latex and peculiarities induced by the smoking process.—Secondary reactions and their prevention.—This latex, it is freely acknow-

FIG. 20.—Smoking Para rubber. The man in the right hand corner is making *Para Sernamby*.

ledged, has special qualities which no other latex has got; but then, consider the care exercised in collecting the latex, and at the precautions in the method of curing to avoid loss, as much by elimination of the mother liquid, as by the antiseptisation of the fermentable or putrescible substances. The rubber is thus placed beyond the reach of secondary reactions, and thus preserves intact all those properties on which its reputation depends. The secondary reaction most to be dreaded is that due to albumenoid fermentable or putrescible proteids under the action of a noxious enzyme. Now, at the very outset, without any scientific

knowledge, and so to say instinctively, the Brazilian aborigines found the best process for paralysing this enzyme.

Effect of regulated heat—Smoke and creosote in smoke.—By methodical and frequently repeated application of a gentle heat, like that from the *fumeiro*, the bulk of the water contained in the serum is eliminated, and the rubber coagulates almost instantly. The *carbon*, produced by incomplete combustion which constitutes the chief part of the smoke, is an energetic antiseptic, and exerts a certain beneficial influence in the Brazilian process. But, besides carbon, *creosote*, a wood-distillation product always met with in this smoke, is the antiseptic *par excellence* of nitrogenous matters, and it is to its action that the superiority of the smoking process used in Amazonia is chiefly due. Whether the use of palm nuts as fuel causes a more energetic production of antiseptic bodies than the ordinary wood used by the Upper Amazonian collectors, is a moot question still to be elucidated. Their use is possibly due to the more abundant disengagement of smoke, and thus of antiseptic bodies. Sulphur, says Collins, plays a certain rôle in the preparation of Para rubber. "I believe too that the vapour of sulphur plays a part in the preparation of some of the Para caoutchouc." The authors do not believe anything of the kind; leave sulphur its acquired quality as a vulcaniser of caoutchouc; it is great enough, and do not let us allow it to intervene inconsiderately where it has no footing.

Summary.—Elimination of water.—Exclusion of air-bells and serum.—Uniform distribution of finally divided antiseptics throughout the mass.—By the oft-repeated intervention of heat, always on minimum quantities, the greater part of the water is eliminated from the caoutchouc. Its presence would constitute one reason for disqualification. This same heat applied to each successive coat of rubber, and each coat is infinitesimally attenuated, prevents interposition of air-bells, or globules of serum, which might cause fermentation of the nitrogenised bodies present in large quantity in the latex. Powerful antiseptics used in a state of extreme dilution throughout the mass of the rubber completely suppress the deleterious action of fermentescible nitrogenous substances.

Trial of the smoking process in New Caledonia and Loyalty Isles.—A tentative imitation of the smoking process of Amazonia was used with great success by MM. Grandjean and Weser, *concessionnaires des Banians de l'État* in New Caledonia and the Loyalty Islands. Dr. Davillé (*On the Colonisation of the New Hebrides*, Paris, 1895), says: "The extraction process is most simple, and requires but a slight equipment; it is that of the *tigelinhas* of Brazil. The operation requires a conical elongated gutter in the form of a hollow prism with a lower edge terminated on one side by a cutting blade, and on the other by a hook. The blade is used to make the incision 8 to 10 centimetres (3 to 4 inches) in length through the whole thickness of the bark; the gutter remains fixed in the lower part of the incision, receives the juice which follows the channel, and thus arrives at the other end, to the hook of which is hung a small conical, white-iron goblet, capable of containing 10 to 15 centilitres (*i.e.* 100 to 150 c.c., or, say, 3½ to 5 fluid ounces). It is easy for the workman to fix the goblets at daybreak, and return three or four hours afterwards to empty them into a gourd, or, better still, into a white-iron can, and replace them on the tree." The other operations are conducted on the Amazon principle. The product is very fine and constitutes a very valuable rubber.

But in attempting to apply the smoking process to other latices than *Hevea*, it is well to bear in mind that the latex of *Hevea braziliensis* is alkaline (the addition of a solution of ammonia preserves it indefinitely from spontaneous coagulation). The coagulation of the latex, by exposing it to the smoke of the urucuri nuts, is doubtless brought about partly by heat and partly by the action of the acetic acid contained in it. The latter and the creosote further tend to preserve the rubber. The smoking process would appear to be only applicable in the case of latex possessing alkaline properties. It is unsuitable in the case of the latex of the *Castilloa elastica*, as this has an acid reaction towards litmus paper, hence alkalies are used.

Different varieties of Para, Para grossa, Para ½ fin, Sernamby or Negroheads.—This description of the process of preparing *Para fin* ends with some details of the origin of the sort called *entrefina*, or *Para grossa*, *Para ½ fin*, and finally of that called *Sernamby* or *Brazil Negroheads*. From the pellicles or skins of rubber taken from the *tigelinhas*, or from the lips of the incision on the tree, the collector prepares a second sort by agglutinating such débris together on the end of a handle, so as to shape them into a flattened ball, which he dips from time to time into fresh latex, which he thus also "smokes" after each immersion. When the block is of sufficient size, the *cauchero* dips it several times in the dish containing the fresh latex, and holds the finishing coating in the smoke each time. He thus gives it the appearance of *Para fin*, but the appearance is only superficial, and no longer deceives any one. The buyer has now become distrustful, and examines the fresh section. It is then seen at once that the substance is not homogeneous. If the properties of this substance approach *Para fin*, that is not to say that they are identical. There is a large quantity of non-eliminated water, a notable proportion of non-antisepticised nitrogenous bodies, coming especially from the portions detached from the lips of the incision, which have been coagulated by natural heat alone. When this method of coagulation is examined, the inherent defects of *Para entrefina* will be evident. The projecting seams of the moulds on the cakes of *Para fina* and *entrefina*, the scraping of the moulds, the coagulated residuum of the latex in the *tigelinhas*, the calabashes, and the latex tubs—all the waste products, in fact—are made into blocks which are packed into "returned empty" boxes or old casks; the whole mass agglutinates into a block which assumes the form of the receptacle in which it is placed. This altogether inferior kind constitutes the *Sernamby* or *Para Negroheads*. It is the least valued of Para rubbers, and justly so. It is often very moist, containing serum and even non-coagulated latex; it has received no antiseptic preparation, and contains, moreover, animal and vegetable débris.

Coagulation by moist artificial heat or boiling process.—A Mexican method.—Description.—This process, adopted by the Mexican Indians in the coagulation of the latex of the *Castilloas*, is primitive; whether they incise the tree or puncture it, they collect the latex in the hollow of a piece of bark or in a pot, transfer the previously strained latex into a cauldron, and underneath the cauldron set fire to some twigs and branches. As with animal milk, there is formed a creamy layer which, on prolonged boiling, coagulates, and the serum soon separates completely from the rubber which it held in suspension. The indiarubber thus obtained is spread on plates, dried and pressed, to eliminate, as far as practicable, the water which it contains.

Criticism — Inherent defects — Visible impurities.—There is no need for a lengthy examination of this process to discover its weak points. Boiling does not sterilise indefinitely the fermentable and putrescible principles of the milky juice. The compression of the sheets does not remove all the moisture, and the method of obtaining the latex is not so carefully gone about as to prevent the presence of all vegetable and mineral impurities, in spite of the straining before boiling. Facts confirm this theory. The section of the sheets obtained by the boiling processes exposes pockets full of a thick greenish liquid embedded in a blackish rubber, mixed with sand and the minute débris of wood.

Another and better Mexican method—Sea salt as a coagulant.—Mexico now produces a new kind, of a bright amber-brown colour, from the same milky juice of the *Castilloas*, which when cut does not show either sand or organic débris. This remarkably nervous rubber, like Brazil rubber, only loses 12 to 15 per cent. in handling. Data as to its preparation are still awanting, but sea salt is possibly the coagulating and antisepticising reagent. Coagulation by boiling is also adopted in British India, in the preparation of the Assam rubber extracted from the milky juice of the *Ficus*.

Coagulation of the latex by natural heat, the soil acting as an absorbent of the water and of the nitrogenous putrescible bodies contained in the serum—Chiefly a West African process.—Coagulation by natural heat is adopted more especially

in West Africa. That is not to say that it is not used elsewhere; but such processes, defective in every way, are the chief cause of the inferior quality of the resultant rubber, and the depreciation which follows as a natural sequence would appear to be the special fate of the Africans, whose indolence is only equalled by their greed. This process is practised to a slight extent by certain tribes of the Congo and Angola, who work more particularly the *Landolphias* of their forests.

Description.—According to Jeannest, the negro of these coasts is content to tap the tree, caring little or nothing whether the wound injures the plant or not. So long as he gets what he wants—an abundant collection—other matters çoncern him but little. The juice flows naturally on to a soil from which the rubbish has been but imperfectly cleared. In the track which it thus follows, under a scorching sky, the milky juice at the outset loses a portion of its water. On the ground, which it reaches in a semi-solid state, it evidently solidifies completely, giving up the remainder of its serum to the dry hot soil, which surrounds the vine which he has tapped. All that he has now to do is to lift his rubber and deliver it to the dealers.

Criticism—Defects.—Is it necessary to examine such a method critically, and is it not comprehensible, without more ample details, that a substance obtained in such a summary manner possesses but few of the requisite qualities of marketable rubber? As to the mineral impurities, present so fatally in the rubber prepared in so rudimentary a manner, the native, instead of avoiding these, too often adds them designedly. If the earth, acting as a filter, draws off the serum and the putrescible bodies present on the surface of the mass, aggregated at the foot of the tree, the lower parts of the coagulum, imprisoned by the first crust, preserve all their serum with its fermentable elements, whether nitrogenous, saccharine, or resinous. These rubbers must perforce remain soft and tacky, and give off a nauseous smell, which must become accentuated afterwards. The waste in manufacture will always be considerable.

Coagulation by natural heat; evaporation on the human body—Also a West African process.—This process, confined to the natives of the West Coast of Africa, if picturesque, seems infinitely superior to the preceding.

Description—Congo and Angola process.—According to R. V. Merlon, the Congo negro, when he comes to a vine which he desires to tap, removes what serves to him as clothing, and, having tapped the tree, collects the milky juice in the palm of his hand, so as to cover the whole of his body with it. This done, he returns to his hut, garbed in this new clothing, removes bit by bit the portions of the juice which the commencement of cohesion has rendered consistent, and makes them into balls for the market. The same process is used by certain tribes in Angola (Welwitsch). After incising a branch, the negro places the palm of the hand against the tree, and lets the milky juice flow along his arm. When it is covered with a sufficiently thick coat, he draws the rubber off, as he would a glove, commencing by freeing the elbow, rolling the rubber on itself so as to make a pad with a hole in the centre, thus stripping in this manner first the forearm, then the wrist, and finally the hand.

Criticism.—This method, without being perfect, and without being capable of producing a rubber exempt from putrescible matter, has yet the advantage of not mixing it with the extraneous vegetable or mineral matters so abundant in the rubbers previously mentioned. It also eliminates the greater part of the moisture by coagulation in thin and often repeated layers, spread over a large surface. This elimination is stimulated by the natural heat which is continuously disengaged from the human body.

Coagulation by natural heat; evaporation on flat surfaces other than the soil—The Brazilian method of preparing Ceara.—This is the special method used in Brazil in the preparatien of Ceara rubber (*Ceara Scraps*), obtained from the latex of the *Manihot Glazowii.* This process is, moreover, frequently used in West Africa and on the Indian continent.

Description.—The following is the manner in which the collectors of the Brazilian

province of Ceara work. The tree, very like the castor-oil plant, is wrought as early as three years, that is to say, when the diameter of the trunk has reached about 5 inches. The *seringueiro* clears the ground round about the foot of the tree, and on the spot so cleared he lays down some banana leaves, to receive the latex, which may flow as far as the ground. He then splits the bark, from the foot of the tree up to a height of 5 feet, in several places and in different directions. The *Manihot* latex, thicker than that of the *Heveas* and *Castilloas*, flows slowly, and only reaches the ground rarely, and then in minute quantity. The greater bulk solidifies on the bark of the plant and agglutinates there, as a long flow of tears, similar to those found on the trees in our gardens. The collector leaves them there for several days, to facilitate drying; he then detaches the tangles, either rolling them into a ball, or re-folding them on themselves. Without any further preparation, the product is put on the market as *Ceara Scraps*.

Different Qualities of Ceara.—The *first* quality is a blonde rubber, collected in the beginning of the season; the *second* quality, more brown, is collected later on, when the first rains commence to fall; the *third*, earthy quality, collected at the foot of the tree, and consequently often contains considerable quantities of earth and sand added accidentally, or intentionally, so as sometimes to reduce the industrial yield to below 50 per cent.

Criticism—Defects.—A substance so prepared naturally contains a quantity of mineral and vegetable substances which materially reduce its value.

Properties of Ceara Rubber.—Ceara rubber has a fine, almost translucent amber colour. It does not become opaque and white, except under the action of energetic stretching. This phenomenon, only met with by Morellet in this class of rubber, is due to numerous ruptures in the interior of the mass, creating empty spaces, which split up the luminous rays tending to traverse this body.

Smell.—Ceara rubber gives off a rather strong smell, and soon becomes nauseous if exposed to the combined action of heat and moisture.

Yield.—In the pure state it furnishes an industrial yield of 75 to 80 per cent., and is endowed with great resistance; the demand would be much greater, if it were not for its defective preparation, and its *quasi*-sophistication by mineral and vegetable matters, always present if in very variable quantities.

The latex of the Manihot compared with that of the Hevea.—The *Manihot* latex is at least equal, if not superior, to that of the *Hevea*. The quantity of fermentable nitrogenous matter is lower, the amount of water is less, and yet the industrial yield of pure rubber is only 75 to 80 per cent. Moreover, the rubber is difficult to preserve, and requires a dry cold place; the putrescible proteic matter which it contains is evidently the cause. Its greater consistency renders *Manihot* latex more difficult to handle than *Hevea* latex, but the obstacle does not appear insurmountable; and here is what should be done:—

Suggested improvement.—Instead of allowing the latex to flow along the plant, it should be collected in *tigelinhas*, previously furnished with a little alkaline water. The fresh milky juice mixes well with water, and, better still, if slightly alkaline, it could thus preserve its liquid state for a certain time, so that it could be coagulated by smoking, so successful in Amazonia. The secondary causes which react so injuriously on Ceara rubber and depreciate its intrinsic value would thus be suppressed. This experiment has been successfully tried in Ceara. But the native collectors do not take to it; it is too troublesome, and they prefer to stick to their old—more expeditious and less burdensome—ways.

In Ceara, the *Manihot* of arid granitic heights yields a highly concrete, scanty latex; but prospers equally well on the plain and on humid ground. The milk is more abundant, and lends itself easily to the above treatment.

Another suggestion.—Experiments might be made on the coagulation of this latex by natural heat, aided by small quantities of common salt; this process, described a little further on, yields quite satisfactory results. In this later experiment, the smaller the blocks the better the rubber; desiccation goes on better the more numerous the evaporation surfaces.

Ceara Sernamby.—In Ceara, the *Manihot* does not everywhere uniformly yield rubber latex. Whether the difference lies in the climatic or thermal conditions, or in a degeneracy on the part of the plant, certain regions in which the *Manihot* likewise grows would appear to be little capable of being exploited for rubber. The tree, when tapped, only exudes a few drops of latex, and the flow stops almost instantly. This barrenness is, however, only apparent. The incision made at the foot of the tree, quite near to the tubercules formed on the root, causes a very abundant gummy liquid to flow, which the native knows very well how to put under contribution for making *Ceara Sernamby.* But the work is done carelessly, and the product so obtained, mixed with the sand and stones on which the latex has been spread, is almost unsaleable, although it has really the same properties as *Ceara prima.* It would, however, be easy to coat the excavation made in the soil before the incision with a layer of moistened clay. The sole so formed, after drying, would rapidly drink up the mother liquor, and a rubber would be thus obtained quite as pure and fine as that of the elevated plateaux.[1]

Coagulation by creaming after doubling the volume of the latex with water, followed by more or less prolonged standing—Localities in which applied.—In Bahia to the latex of the *Hancornias*; in several localities of Nicaragua and Central America to that of the *Castilloas*, as well as in Assam to that of the *Ficus.*

Description.—In Bahia, the latex, left to itself, after its volume has been doubled with water, separates rapidly into two superimposed layers, the upper part of which assumes a buttery consistency; it is dried, and, as soon as it has sufficient homogeneity, it is put on the market. In Assam, the rubber so prepared is gently heated in pans to accelerate drying and render the product less humid. In Central America, the cakes so obtained are first pressed with wooden rolls, which remove the excess of water and suppress some of the pores; sun-drying completes the process in fifteen days, when the rubber is ready to be rolled and packed.

Criticism—Defects.—This rudimentary method yields a very inferior quality, which often loses more than 50 per cent., especially when fresh. When cut, not only does water—more or less charged with foreign bodies—escape, but also a certain quantity of uncoagulated latex, and it is easy to prove that it is really latex—(1) by the microscope; and (2) by simply pressing it between the index finger and thumb, the heat of the fingers induces coagulation, and the rubber may be drawn out into elastic filaments by withdrawing the finger and thumb from one another. Hence the bad repute of a product whose effective rubber is in no way inferior, in regard to elasticity and resistance, to many other sorts.

Coagulation by standing for a greater or less length of time after diluting the latex with five times its bulk of water, and drawing off the water—A Congo process.—The process, used for *Landolpia* latex in the Congo, consists in making incisions, which penetrate just under the bark of the vine without reaching the heart of the plant, because the latter contains *another milky substance, but highly diluted with water and acid, which rapidly decomposes.* The incisions are longitudinal or oblique, and made the one below the other. Underneath the lowest incision the native fixes by means of potter's earth, or, better still, semi-coagulated juice, a rather wide, curved leaf, which leads all the juice which flows from it in a thin thread into a calabash laid at the foot of the tree. The vessel into which the juice flows is pierced in its base by a hole, which is carefully corked. At the moment of extraction the juice is fluid, and very much resembles milk, thickened by prolonged boiling. To this juice the negroes add four to five times its volume of water.

This dilution, and also the influence of the initial acidification, facilitated thereby, induces the hydrocarbide elements to solidify on the surface into a sort of thick cream; twenty-four hours afterwards the cork which closed the inferior orifice

[1] The *Manihot* is being cultivated in Mozambique on the large scale, and the trees tapped and the latex prepared with all the care that science, backed by abundant capital, can command.

of the calabash is removed, the aqueous portion flows away, and with it the major portions of the putrescible elements; the rubber remains at the bottom of the vessel in a semi-fluid state. To hasten coagulation, the negroes pour it into wooden vessels, and expose it to the air for some hours.

The solidification is then more advanced without being complete. It is the moment which the negroes think opportune for kneading it into balls. Sometimes the rubber which is found in the bottom of the vessels is too consistent to lend itself easily to kneading. It is then cut into small cubes or thimbles (hence the commercial name of *thimbles*).

Criticism—Defects.—This method, like the preceding, incorporates with the rubber a certain quantity of serum, and even of undecomposed latex, and consequently fermentable substances which soon impart a characteristic nauseous odour to these sorts. Nothing is done, with the exception of imperfect washing, to sterilise these substances and prevent ulterior decomposition. The rubber, so produced, has therefore all the inherent defects of the method. Its yield does not exceed 60 per cent. The product is very spongy, and contains in the numerous vesicles of the paste a whitish liquid, which eventually generates the repulsive smell already mentioned. Other samples of rubber, prepared more rationally from the latex of these same *Landolphias*, are exempt from these defects, and owe their qualities to the method of coagulation.

Coagulation by chemical means — By mineral reagents — Applied in both Africa and America.—This process is as expeditious as it is easy. It is not wonderful, therefore, to find it practised both in Africa and in America. Pernambuco, Maranhao, and certain rubbers of the Ivory Coast and Cameroons, are so prepared.

Coagulation by alum—The Strauss method—Description.—This process, used in Pernambuco for coagulating *Hancornia* latex, bears the name of its inventor, Henry Anthony Strauss. It consists in pouring into the latex an aqueous solution of potash alum; coagulation is effected almost immediately. The coagulum is then allowed to drain for eight days on wattles arranged for the purpose. The masses so prepared are divided into small fragments, sun-dried for a month, and put on the market in that condition.

Criticism—Defects.—Strauss's process is ingenious (Morellet), but the results of its application are bad, and the authors in no way share the enthusiasm of J. Collins for this method of coagulation. "This method, purchased by the Local Government of the province of Pernambuco, is very much approved," he says, "the more as it may be performed far from the place of collection, and that it is always done in the cold state." The rubber so prepared goes wrong as it ages, changing into a substance the market value of which is very poor: a piece of Mangabeira of sufficient elasticity at the outset becomes transformed into a sort of bad quality millboard, incapable of resisting strain, and without any elasticity; its molecular state is so far modified as to render it granular and friable. The rubber, of a rose colour both interiorly and exteriorly, is covered with a crystalline efflorescence of alum.[1] When cut, the section shows a large number of pockets, filled with water, not only from the serum imprisoned in the mass by instantaneous coagulation, but also and more especially from the solution of alum used in the process. It would be easy to separate a portion of the alum water by the press; but, even so, the collector has not always a press at his disposal; and if he had, elimination would be very incomplete, and the deleterious action of alum would always make itself felt. If manual labour be economised during collection, the product is deteriorated, and the cost of freight is in no way diminished; it is almost doubled, since the rubber often yields as much as 60 per cent. of water.

It is not likely that coagulation by alum will advance in the future. Manufacturers agree as to the bad quality of the products, and tend more and more to reject them, as appears from the following:—

[1] The defects of this process are evidently due to the formation of resinates, etc., of alumina. The efflorescence points to too strong solutions, as well as imperfect washing.—Tr.

"Mangabeira rubber is obtained from the trees of that name [species of *Hancornia*], found in large numbers in the interior of Pernambuco, as well as of the other northern provinces. The reports which I hear have been received from Liverpool of the reception of this article are far from favourable; the price went up to 2s. 7d. per lb., but has fallen again, and it would appear that 1s. per lb. is about the price obtainable in England in ordinary times. The method employed in the preparation of the rubber is very primitive, and, I think, may easily account for the article not being well received. If the milk were treated in a more careful manner, there seems no reason why the rubber should not be favourably received. At present the plan adopted is simply to mix alum with the milk, which causes it to coagulate; the lumps of rubber are then placed in the sun, after which they are sent to the market. From the defective mode of preparation a great loss of weight afterwards occurs, frequently as much as 40 to 50 per cent., some say even more.

"From Bahia and Pernambuco, in Brazil, comes a rubber of a different grade from that of Para. It is cured with alum and water. The Pernambuco comes in sheets, and is of yellowish white tint; that from Bahia is not so good, and comes in round balls. The principal objection to it is that it is very damp, entailing a large loss to the importer from shrinkage.

"Of Mangabeira rubber there are three grades, very similar to the Bahia and Pernambuco sorts. A grade that has a red look is considered superior, and sells for five or ten cents per pound higher than the others."

2. *Coagulation by sulphuric acid and common salt—Description.*—(1) *Sulphuric acid.*—In Maranho and Matto Grosso alum is replaced—as a coagulant—by dilute sulphuric acid. Sulphuric acid, like all acids, is an energetic coagulating agent. But, besides the well-known transport difficulties, it coagulates the juice too rapidly, and thus does not sufficiently eliminate the mother liquor. Moreover, the acids do not possess antiseptic properties; and it must be condemned for reasons already mentioned. (2) *Common salt.*—A solution of common salt also possesses coagulating properties; its antiseptic power is well known, and it does not present the same transport difficulties as dilute sulphuric acid. The use of acidulated water has thus been generally replaced by common salt in the two provinces mentioned above. The use of common salt alone would be rather to be recommended if no better process were at the disposal of the collector, but *it has the defect of leaving a large quantity of water in the rubber.* Certain Ivory Coast, Cameroon, and Congo rubbers are likewise coagulated by salt water. There is thus a great resemblance between such rubbers and the American rubbers just mentioned.

3. *Coagulations by an aqueous solution of soap — Description.* — Between coagulation by mineral reagents and by vegetable reagents a special method of coagulation, sometimes adopted in Peru, for the *Hancornia* latex, intervenes, and in which a soap solution acts as coagulant. To coagulate the milk, it is either poured into a vessel or into holes in the clay soil, containing about 30 kilogrammes (say 66 lbs.) of liquid. The night before, 125 grammes (about $4\frac{1}{2}$ oz.) of soap are dissolved in a bucket of water. Two buckets of this solution coagulate about 30 kilogrammes (say 66 lbs.) of rubber in the space of half an hour. As soon as coagulation commences, the milk is beaten with the flat of the hand to facilitate the operation. "The indiarubber is afterwards taken away in the form of a block, which is punctured here and there with a knife to free it from water. The punctures are not made very deeply, so as not to diminish the weight of the rubber" (E. Bard).

Criticism.—The rubbers so made are naturally very porous, and this rudimentary method often brings in its train a considerable quantity of extraneous matter. As to the action of the soap solution by itself, it is difficult to understand. Possibly it acts in this case purely and simply by the mass of water which it contains, and that it is the water, as in the previously mentioned processes, which sets the rubber globules free from the too dense latex, and thus enables them to aggregate more easily on the surface of the liquid. The method of collecting and preparing rubber in Peru is to fell the tree and cut it into pieces, limbs and all, and let the milk run out from the wood into holes dug in the ground. It is then

coagulated in these pools by mixing it with ordinary soap. It produces a most vile-smelling compound which sells at about the same price as *Para Sernamby*.

Chemical coagulation by vegetable reagents—Countries where practised, and nature of reagents—Citric acid as a coagulant.—This method of coagulating the latex is practised in the case of some Madagascar rubbers, in Gambia, Peru, Guatemala, and Nicaragua. Sometimes it is a vegetable acid which intervenes, sometimes it is the infusion of a vegetable product of indeterminate chemical composition, but which very likely owes its coagulating power to its more or less pronounced acidity. The African rubbers just mentioned would appear to come from the coagulation of the *Landolphias* by citric acid. "In the course of our examinations we have often observed, in the rubber cakes from Madagascar, seeds with an anatropous ovule with a clearly marked chalaza, seeds certainly of the *Aurantiaceæ*. We did not at first understand how these seeds could be mixed with the indiarubber paste, but they were met with too frequently to be fortuitous, and we were forced to conclude that their presence was due to the methods of coagulation, that they used the juice of the fruits of the *Aurantiaceæ*, and that citric acid was the coagulating agent. This opinion was corroborated by the testimony of persons who had travelled in those countries" (Morellet).

Criticism—Defects.—M. Cousin states that he obtained with this method, during his stay at Casamanca, a superior quality of rubber of a fine amber shade, inclining to a bright horn colour, almost translucid, very sensitive, and of remarkable elasticity. Until proof to the contrary is forthcoming, this assertion may be doubted: if mineral acids produce too rapid a coagulation, thus facilitating the imprisonment in the mass of rubber of too large a quantity of mother liquor and fermentable bodies, vegetable acids have the same defect, and are the natural hot-beds of microbe culture hastening the putrefaction. It is impossible to believe in the excellence of a process where this new drawback has to be added to those already pointed out in coagulation by mineral acids.[1]

Citric Acid replaced by sulphuric acid in Madagascar.—In Madagascar, where citric acid was at first extensively used for this purpose, it has now been completely replaced by the sulphuric acid introduced by the Europeans.

South American Practice.—In Peru, *Hancornia* juice is sometimes coagulated by means of the juice of a climber called *Sachaacamote* by the *caucheros* of the country, likewise the latex of the *Castilloas* of Guatemala and Nicaragua, the coagulation of which is effected by an infusion of the tuberous root of a convolvulus, the *ipomea bona nox*, numerous varieties of which grow in Central America. The decomposition of the milk is effected by means of an undetermined organic acid, but the rubber resulting from the reaction is intimately mixed with a foreign resin, which not only reduces the industrial yield, but which, mixed up in the paste, is difficult to eliminate, and an obstacle in manufacture. Plants producing the latex, so manipulated, yield under other and different conditions a very elastic, sensitive, and profitable product. This leads incidentally to the experiments of Dr. Morisse (member of the expedition of the Upper Orinoco, led in 1889 by Count Bertier) on different methods of treating the latex of the *Heveas*.

Experiments on Hevea Latex.—"Choosing preferentially reagents capable of rapidly coagulating without injuring the quality of the rubber, Dr. Morisse used different products which yielded the following results:—

(1) "One volume of 90 per cent. *alcohol* coagulates 6 volumes of latex, yielding a fine superb rubber of brilliant whiteness, and yellowing but slightly on ageing, but the dearness of alcohol and its feeble coagulating power puts it out of the reckoning.[2] *Liquid perchloride of iron* coagulates in the proportion of 1 to 9 of latex. The rubber so obtained is a coarse powder with an ugly, earthy appearance,

[1] Coagulation by acids—mineral or vegetable—in modern rubber plantations where the rubber is forthwith put through a washing machine, is scarcely subject to the above criticism. Translator's note to 2nd English edition.

[2] This coagulating power of alcohol contradicts Ure's results, but it is hard to say what was the identity of the actual latices he tested. Translator's note to 2nd English edition.

the molecules of which have little cohesion between themselves. (2) One volume of an *alcoholic solution of corrosive sublimate* coagulates 11 volumes of milk, and yields good rubber. (3) One volume of *chloride of calcium* coagulates 15 of milk, but this deliquescent salt is difficult to preserve in a region where the air is constantly charged with humidity. (4) *Monohydrated hydrochloric acid* has a coagulative power of 1 to 5. *Commercial nitric acid* is still more feeble. (5) *Non-crystalline commercial carbolic acid* has a coagulating power of 1 to 18. But the most wonderful of the coagulants hitherto tested is *commercial sulphuric acid.* An aqueous solution of $\frac{1}{50}$ coagulates 10 of milk, and this coagulating power extends as far as $\frac{1}{100}$, but more slowly and by stirring the mixture. (6) *Tincture of iodine* would not appear to coagulate except in virtue of the alcohol which it contains. The other reagents tested gave no appreciable result. Amongst these were the *carbonates and bicarbonates of potash and soda, chloride of sodium, the bromides of potassium, sodium, and ammonium; ammonia, ether, chloroform, carbon disulphide, glycerine, permanganate of potash, arsenious acid*, etc. (7) *Alum*, used successfully with some indiarubber trees, gave negative results with the milk of the *Hevea.*

"*Defects of sulphuric acid coagulation.*—The first sheets prepared by sulphuric acid coagulation were at once attacked by insects and cryptogams, the rapid development of which, in the interior as well as on the surface, spoiled the appearance and quality of the rubber.

"*Coagulation by a mixture of sulphuric acid and an antiseptic.*—Dr. Morisse then mixed the sulphuric acid with an antiseptic, the action of which was most lasting, and carbolic acid possessing in itself a rather high coagulating power gave him full satisfaction. Traces of carbolic acid sufficient to ensure sterilisation do not disappear from the surface until after six months from the date of coagulation. But desiccation is then so far complete that injurious fermentation is no longer to be feared. The final definite formulæ deduced from the results of numerous experiments are as follows:—

Solution A	Commercial carbolic acid	4 Grammes.[1]
	Alcohol in sufficient quantity to dissolve the carbolic acid.	
	Water	80 ,,
		84 ,,
Solution B	Commercial sulphuric acid	2 ,,
	Water	20 ,,
		22 ,,

How to use Morisse's Coagulants.—"Mix the two solutions before use. This quantity of mixture instantly coagulates a litre of milk by the aid of slight agitation. Even a mixed solution of $\frac{1}{60}$ for the first acid and $\frac{1}{30}$ for the second is sufficient in ordinary weather, but the hour at which the work is done must be taken into account, the temperature, the hygrometric state of the air, have an incontestable influence on coagulation. In fact, on certain days it is effected slowly and with difficulty with the second solution. It is therefore advisable only to put the strong solutions A and B into the hands of the operators.

"*Cost of coagulants a negligible quantity.*—In order therefore to coagulate and asepticise a ton, say 1000 litres, 2 litres of sulphuric acid and 4 litres of non-crystalline carbolic acid would be required. The cost of chemical coagulants may therefore be completely neglected.[2] One hundred kilogrammes of Para rubber were obtained by this process, white, hard, resistant, compact, and pleasant to the eye. The practical proof of the success of the process has thus been demonstrated. It results from the preceding that the reagents capable of coagulating the

[1] This gives a total of 106 grammes; and as that amount precipitates 1000 grammes, 106 oz. will also precipitate 1000 oz., that is as near as may be 17 oz. to 1 gallon.—Tr.

[2] The figures in the formula are given by weight; but in this calculation by measure this will lead to error, as carbolic acid is rather heavier than water, sp. gravity 1·060; whilst concentrated sulphuric acid, sp. gravity 1·840, is nearly twice the weight of water.—Tr.

latex of certain plants have no effect on the latex of the *Hevea*. Moreover, it does not appear to us that attempts to substitute a new method of coagulation for the smoking process should be encouraged. The collectors would probably readily take to any process of simplifying the long and tedious operation of smoking, but we need not study their convenience but rather the result obtained. Now we have determined that rubber prepared by the addition of certain solutions is of inferior quality, etc. etc."

The authors perfectly agree with M. Rousseau on the value of the process published by Morisse. Para rubber owes its excellent quality especially to its difficult method of preparation; full of minute details, to depart from it would be to court inevitable mistakes, which would resolve themselves into considerable loss of money. Moreover, they have no faith in the antiseptic action of carbolic acid; creosote alone, applied on each layer by aid of a gentle heat, is capable of producing complete sterilisation and of destroying the secondary influences to which we have already referred.

4. *Coagulation by natural or artificial heat and chemical coagulation combined—Practised in Mozambique.*—The reader's special attention is drawn to this method, and the reasons for so doing will be given after having described the process. The milk of the *Landolphias* and other vines in Gambia (Casamanca, Ivory Coast) and Mozambique is coagulated as follows:—

Description.—The collector taps the vines very slightly; he somewhat bruises the bark. The shallow incisions are 5 to 6 centimetres long (say about 2 to 2¼ inches), their width varies with the size of the vine; the incisions are very close together, about 4 inches apart. After the bark is cut the latex soon exudes, white and thick. The native, by aid of a shell, immediately besprinkles each incision with a little salt water, which dissociates the serum from the rubber. The latter is instantaneously coagulated into small lumps. These the collector draws off each incision to form a kind of nucleus, which he rolls between his hands. He draws the nucleus to him, and the latex, continuing to flow and solidify, is drawn out into filaments. There are thus as many filaments as there are incisions. The native, as he draws these filaments to him, winds them on to the initial small nucleus, moistening the incisions from time to time with salt water. The traction and subsequent compression between the fingers causes the central filaments to coalesce as they are covered. The threads are apparent only on the outside; only a small part of these balls can be afterwards unwound. Almost white in the beginning, the envelope of rubber browns with time, and turns reddish. The weight of the balls varies between 300 and 800 grammes (roughly, between 10½ and 28 oz.), but the negro sometimes makes masses of more than 2 kilogrammes (say 4½ lbs.). As these balls are very bulky, and as the workman cannot easily hold them between the fingers, he lies on the flat of his back and continues to wind the rubber, supporting the ball with his hands and the pit of his stomach. The operation is continued until the flow of juice is exhausted (Chapel).

Criticism—Merits of the process.—This process, where natural and artificial heat as well as a powerful antiseptic, common salt, are constantly coming in contact with the most infinitesimal quantities of rubber, is very useful where smoking is not possible, either on account of the local dispositions of the country which yields the latex, or on account of the more or less thick nature of the secreted juice. Each filament is in contact both with the exterior air and the hand of the operator; the evaporation of the serum is thus greatly facilitated whilst the common salt is constantly antisepticising the whole. The operation is tiresome, yet if Nature be bountiful in furnishing us with raw materials for our industries, it involves a certain effort on our part to profit as far as possible therefrom. Coal-mining is laborious and metals are not obtained without great effort; no one complains of the total work expended if the result be profitable.

Purity of the product — Bad effect of natives' malpractices.—This process has another advantage: it facilitates the production of a rather pure product,

without admixture of extraneous mineral or vegetable matter, unless the collector feels bound to add these substances to increase the weight of the goods. But the buyer will do justice to such misdeeds, and the natives cannot be too much admonished against their very marked tendencies towards these malpractices. Ill-repute rapidly strikes their raw material, and it is always difficult, and sometimes impossible, to induce the trader to resume the route which he has abandoned on accounts of a bad deal.

5. *Separation of the indiarubber by churning—The process inherently defective.*—A few lines are devoted to the method proposed by M. Rousseau for coagulation by simple churning. The notion is seducing: to churn the latex, as cream is churned in butter-making, is an easy enough operation, but it has a grave defect which will never allow of this conception being adopted in actual practice. Butter, once separated from the butter-milk, abandons by a slight pressure—whether mechanical or by hand—almost all the serum which it has imprisoned; kneading with table-salt antisepticises it for some time, but rubber does not yield to pressure or kneading in the same way without sufficient desiccation and antiseptisation. The rubber thus obtained, even with the best juices, would have all the previously mentioned defects.

Summary of the best methods adopted for obtaining raw rubber—(1) *The process must vary with the density of the latex.*—In choosing a rational method for coagulating the latex, regard must always be had to the density of the juice. The *Landolphias* and *Manihots* yield a thicker milk than the *Heveas*, the *Castilloas*, and the *Ficus*, and the same method of coagulation cannot be used indiscriminately.

(2) *A pure product always to be aimed at.*—It is necessary, whatever process may be adopted, not to forget that the object of coagulation is to produce an article as exempt from water and fermentable substances as possible, whilst it at the same time frees it from all inert foreign bodies, which can only impart to the product a sophisticated appearance, which perceptibly depreciates it, whether the addition be intentional or not.

Processes recommended.—From this point of view, two coagulation methods specially recommend themselves to the attention of collectors, namely, that marked 1 *a* I. *Coagulation by artificial heat or smoking*; and 4. *Coagulation by natural or artificial heat, with the intervention of common salt.*

(3) *Injurious action of acids and alum and dilution with water.*—The use of acids—mineral or vegetable—that of alum, as well as the addition of water in any form, are always injurious to the quality of the product, and ought to be carefully avoided in coagulation processes.

(4) *Influence of shape and size.*—The size and shape given to the mass of rubber is not without its influence on the quality of the product, and we have often remarked, chiefly in the methods in which an aqueous liquid intervenes, that the product is more defective the greater its bulk. This is easily explained. The more the surfaces are renewed in the drying of the same quantity of matter, the greater is the evaporation, the rubber gains in quality, and the greater desiccation diminishes the ulterior action of ferments.

(5) *Evil effect of mixing the milk of different trees.*—In order to obtain a rubber endowed with the maximum of good qualities which a latex is capable of producing, it is necessary to carefully avoid mixing the milks of different rubber trees: for one reason or another, the one is always inferior to the other with which it is associated. In such a mixture the inferior sort always reacts on its neighbour, and not only depreciates its value, but its properties are really more or less altered.

(6) *The desirability of ascertaining the chemical composition of the latex.*—A knowledge of the exact composition of the latex of each species would aid greatly in the selection of the best method for coagulation of each individual rubber.

Absence of data.—Unfortunately, sufficiently exact data are wanting. It is to be regretted that this work has not been already undertaken, for it would render immense

service to the rubber industry, and it is to be hoped that in recording the importance of the gap the attention of chemists and naturalists will be aroused. Adriani, in his study of the latex of the Indian *Ficus*, adopted the best methods of analysis. In the following chapter an effort has been made to study the latex of the *Hevea* under the most exact conditions possible. It would be necessary for the same work to be done with each variety of latex produced by the different plants of each country; a powerful factor would then have been gained in the elucidation of such important questions as the best methods of coagulation and the preservation of each of the natural varieties of rubber.[1]

(7) *The necessity of ascertaining the intimate structure of the laticiferous vessels.*—The exact knowledge of the intimate structure of laticiferous vessels, their arrangement and development as regards the other organs of the bark, would also be of the greatest assistance in such a research. But little has been done in this direction, although it might bring a fresh light to bear on the originating influence, on the quality of the rubber and its most appropriate treatment. The authors only know the micrographical work of M. Morellet upon some rubber barks. This example would be a good one to follow, particularly on the spot. However that may be, use has been made here of the slight amount of material published by this *savant*, and it is to be hoped that he will not leave such an interesting work unfinished.[2]

[1] This has now been done, or is being accomplished.

[2] Recent resino-micographical literature abounds in data of the type here desiderated. Much interesting work has been done of recent years on the minute structure of laticiferous vessels, for a survey and bibliography of which see *Tschirsch's Harze und Harze Behalter*.

CHAPTER III

RUBBER CULTIVATION IN VARIOUS COUNTRIES

CLIMATOLOGY—SOIL—RATIONAL CULTURE AND ACCLIMATISATION OF THE DIFFERENT SPECIES OF INDIARUBBER PLANTS

Influence of methods of collection of latex, and separation of resin, on quality.—If the richness of the latescent juice of indiarubber plants vary with the nature of the plants producing it, their age, their surroundings, with the season and even the hour of harvesting, the quality of the latex, and therefore that of the indiarubber, obtained from it, may also vary, according to the method of collecting the latex, and the process of separation of the resin, disseminated through it. *Influence of genera and species.*—The diversity of the plants yielding the latex need not be insisted upon any further. We reserve our description of the importance of the plant until the merits and defects of each commercial variety of indiarubber falls to be discussed.

Influence of age.—The influence which the age of the plant exerts in the production of the latex is important. Extreme youth, like extreme old age, is prejudicial to the productive force in the vegetable kingdom as well as in the animal kingdom. The *Hevea* of Brazil do not commence to be remunerative before the age of fifteen to twenty years, and that it does not become exuberantly productive under twenty-five years, without reaching decay in a hundred. The *Manihot* of the same country yields profitably as young as ten years, and the *Urceola* in its fifth year.

Influence of the age of the plant on the nature of the latex and the abundance of its flow.—This point has been studied by several authorities, amongst others by Wright, by Proudlock, and by Perkin :—" Some laticiferous plants yield rubber of good quality when quite young, but this cannot be said of the *Hevea*, *Castilloa*, or *Manihot* species in Ceylon. The cortex of the seedling of *Hevea braziliensis* and the cotyledons of the seed itself possess a large number of laticiferous channels, but the latex obtainable therefrom is usually very sticky and the dried product of low commercial value. Rubber prepared from two-year-old trees of *Hevea braziliensis* is sticky and easily snaps when lightly stretched ; that from four-year-old trees or from stems which have a circumference of about twenty inches, though it does not possess the properties which manufacturers most desire, realises a price which is, to the producers, satisfactory. When a tree is tapped for the first time, though it may be four to twenty-nine years old, the rubber obtained from the latex is apt to turn soft, sticky, or tacky on keeping ; this is usually accounted for by the large proportion of sap contents which are unavoidably mixed with the latex when the original incisions are made, the sugars, gums, etc., from the cortical cells providing a good food supply for bacteria responsible for the development of tackiness in rubber. Subsequent tappings of trees of these dimensions usually give good rubber when the tapping operations are carried out on the basal part (base to 5 or 6 feet)."—Wright, *Cantor Lectures.*

Proudlock, curator of the Government plantations on the Nilghiri Hills, found that *Castilloa* trees three or four years old, in the Barliar plantation, 2,400 feet, yielded a gummy substance destitute of the properties of true rubber. Fifteen

months later these selfsame trees yielded a better quality of rubber, hence he concludes that the change from yielding a gummy substance to yielding a true rubber, coincides with or closely follows the period when the species first begins to produce seed.

TABLE VI.—NATURAL HABITAT OF INDIARUBBER PLANTS.

Country.	Altitude.	Indiarubber Plants best adapted for Climate, etc.
South America	Plain.	*Heveas.*
		Micandras.
	Heights.	*Manihots.*
		Hancornias.
Central America	...	*Castilloas.*
West Africa	...	*Landolphias.*
		Vaheas, Callotropis.
East and Central Africa . . .	...	*Vaheas.*
		Landolphias.
India	...	*Ficus.*
		Willughbeia, Cynanchum.
		Cameraria, Chavanesia.
Oceania	...	*Ficus, Urceola.*

Soil.—It has been assumed for a long time that swampy land, exposed to the action of the tropical sun, is alone adapted for the growth and development of indiarubber trees. This assertion, if true as regards the *Hevea* of the Amazon, is not so as far as the *Hancornia* or the *Mangabeira* of the sandy soil of Pernambuco, Maranhao, and Bahia, nor as regards the *Manihot* or *Manisoba* (*leitera*) of the arid and granitic rocks of the province of Ceara. This plant resists the driest weather, and, whilst every other form of vegetation is destroyed under the influence of a scorching wind, it thrives and yields generously a profitable latex.

It must, however, be acknowledged that vegetation is much more intense in ground exposed to inundations or drenched by the periodical rains, and that the combined action of heat and moisture is essentially favourable to the development of indiarubber plants. If the soil on which they grow be marshy, or greatly soaked by the rain, or by the prolonged sojourn of the water along the banks of the rivers, the latex will be watery and, consequently, poorer in resin. If, on the contrary, the same plant be situated on dry ground, exposed to the heat of a torrid sun, the latex will be less abundant and more difficult to collect, but it gives a larger proportion of resin.

Moreover, this influence of an excess of humidity brings in its train very unsatisfactory results so far as the harvest is concerned, when the rains have persisted longer than the customary time.

Ratio of indiarubber to latex.—However that may be, the yield of the latex in indiarubber may vary from 15 to 40 per cent.; below 15 per cent. the trees are not wrought, the results being no longer profitable.

ACCLIMATISATION OF INDIARUBBER PLANTS.—EARLY HISTORY.[1]

The question of soil brings us naturally to that of the *rational culture of indiarubber plants* and to that of the *acclimatisation of the different species* from one hemisphere to another.

In British India.—In this respect, the British, essentially practical, and always zealous to free themselves as far as possible from paying tribute to foreign countries for the acquisition of raw materials employed in industry, have not

[1] Recent developments must have perforce modified the views of the authors on the acclimatisation of rubber. This section (pp. 57–63) is retained as of purely historical interest.—Translator's note to second edition.

hesitated to introduce into their Asiastic colonies the rational culture of indiarubber plants, and to try to acclimatise those most adaptable to the soil and climate of Asia. These experiments are on the point of being crowned with full success. In their intention to make India the indiarubber-producing country of the world *par excellence*, the British were, to a certain extent, encouraged in their enterprise by several reasons, which contributed to present this design under the most alluring colours.

Inducements leading to attempts at acclimatisation.—In Amazonia the rubber trees had been treated in such an irrational manner, that many of the trees and the best were annihilated, and consequently the *seringueiro* had been constrained to penetrate farther and farther into the solitude of the virgin forests. On the other hand, the Brazilian Government, as well as the local authorities of the productive provinces, had imposed on indiarubber an export tax, levied at the place where it was wrought; then it capped that with an *ad valorem* duty of 21 to 22 per cent. (9 per cent. on account of local customs dues and 11 to 13 per cent. for provincial taxes). This taxation, moreover, was not the only imposition. The formation of a syndicate of Liverpool speculators, desirous of cornering the world's market of indiarubber, had still further contributed to raise the price of the article beyond what it would ever have been if the ordinary rules of supply and demand had been followed. These considerations were bound to influence a Government mindful alike of its industry and commerce. There was, however, a dark side to the picture. The cheap rate at which indiarubber was produced by plants growing wild was brought forward as an objection. What had the collectors to do with rational culture, when it was only necessary to penetrate a little farther into the virgin forest, where abundant vegetation presented itself to them? Could a colonist, however intelligent he might be, hope to enter into serious competition with such a rival? This objection was victoriously fought. If the indiarubber tree is only to be found in the virgin forest, has not the harvester to undertake a long and tiresome journey of several weeks' duration before arriving thereat, and before finding the most convenient place for fixing his hut? Is he not frequently under the necessity of changing his abode until he has collected enough to cover the expense of his journey, his stay, as well as his return, without speaking of the profit to be realised—a profit which enables him to live during the rainy seasons? Is he not far removed from the settlers who would buy his harvest from him? and the far from conscientious dealers, are they not there for the express purpose of working upon his extreme distress on his return, and to acquire dirt-cheap the product of his work?

The colonial planter's advantages over the Indian.—However small may be the wants of the Indian, he will never produce with so little cost, and so much quietude and peace, as the colonist in his enclosed plantation. The British had already had a striking example of this in the culture of cinchonas. Hence they passed over these specious objections, and continued on the road which they had mapped out for themselves. It was quite natural that the first attempts should have been brought to bear on the rational culture of the indiarubber tree indigenous to the country itself, the *Ficus indica*. This tentative had, moreover, become urgent, in consequence of the ever-increasing destruction by the native collectors of the natural trees in existence at the time; and, under the risk of seeing this branch of national production perish for ever, it became necessary to replace the ever-decreasing trees.

Rational culture of rubber first attempted in Assam.—The first attempt to form plantations was made in Assam in 1860. The experiment furnished sufficient data to be able to count upon the success of an undertaking of this kind.

Yield of a Ficus in rubber—Amount and intervals.—It is only after twenty-five years that the *Ficus* can actually furnish a profitable yield. From that time forward the tree will yield every three years; to expect more from it would be to condemn it to rapid impoverishment. At the age of fifty years, each *Ficus* should furnish a triennial harvest of 20 kilogs., say 44 lb. of indiarubber.

Cause of failure—Imperfections of Ficus rubber.—This calculation was not so attractive, considering the time that had to elapse before drawing any profit from a plantation. Analyses and experiments undertaken at intervals proved, moreover, that the *Ficus* by its own milky juice could not, no matter how perfect were the methods of preparation, furnish an indiarubber equal to that of Para and Ceara. These experiments were therefore condemned, and the Assam plantations were temporarily discontinued.

Equally futile attempts to acclimatise the Urceola elastica and Urceola esculenta.—Trials were then made with the *Urceola elastica* of Borneo, the development of which is so rapid that as early as the third year it yields its first crop. Moreover, the plantation once established requires no other care whatever. But, without knowing the reason, it would appear to us that no serious attempt was made in this matter. The same holds good in regard to the *Urceola esculenta*, the preliminary establishment expenses of which are very much below the average, and which furnish by the seventh year a yield varying between $\frac{1}{2}$ and $2\frac{1}{2}$ kilogs. ($1\frac{1}{8}$ to $5\frac{1}{2}$ lb.).

Still further futile attempts at acclimatisation—Trials with the Castilloa.—The British, especially struck with the really remarkable qualities of American rubber, directed their efforts particularly in that direction. But it is a remarkable thing that in their trials they did not start with the *Hevea braziliensis*, but rather with the *Castilloa elastica*, which yields a much inferior rubber. In 1875, Robert Cross was entrusted by the director of the Royal Botanical Gardens of Kew with a mission to Central America, with the object of procuring slips, cuttings, and seeds of the different species of *Castilloa*, intended to be multiplied and propagated in glass-houses, for ultimate distribution amongst the different British colonies. This system, which is adopted by the British, in a general manner, for all the plants which they wish to acclimatise in their colonial settlements, is not, however, without a flaw. Because a plant succeeds in a perfectly well-regulated greenhouse, under the hand of educated and skilful gardeners, with care bestowed upon it, which it would be impossible to give it in the open field, it does not follow that the plants will inevitably succeed on the spot to which they are eventually transplanted. Hence arise innumerable deceptions, where there have been every ground to hope for success. That is exactly what happened with the *Castilloas*: whilst they prospered in the Kew hothouses, they perished in the Indian plantations in default of the soil and climate of the mother country. These trees, in fact, prosper more especially in the dense moisture-saturated forests of Central America, on the banks of the rivers on the Atlantic side of the watershed or "divide." In the producing districts *par excellence* of this indiarubber tree, namely, in the basin of the Rio San Juan, it rains nearly nine months of the year, and that is *par excellence* the climatic conditions essential to the perfect growth and development of the *Castilloas*. These trees will never succeed in marshy ground, but are especially fond of humid but arable land.[1] Reproduction is easily effected by *marcots* (branches covered with soil without being detached from the main stem, so that they may take root; in Britain the branch is called a layer, and the process is known as layering) detached from the young branches, but these *marcots* or layers never assume a very vertical position.

Futile attempts to acclimatise the Hevea braziliensis.—In the following year (1876) Robert Cross was sent to Amazonia to get slips and seeds of the *Hevea braziliensis*. In spite of the ill-will of the natives, jealous of preserving the monopoly of so highly profitable a product, he succeeded in his mission, and the *Hevea* was brought to augment the richness of the acclimatisation gardens of Kew.

Cause of failure.—This tree prospered well in the hothouse, but suffered in its turn the fate of the *Castilloas*, and for the same reasons, in the bare, exposed country plantations. The thing was easily understood: the *Hevea* subsisted under

[1] Manson recommends *Castilloa* trials on hillsides with western aspect. It thrives on hills of Southern India, near Calicut and Malabar, and is a tree for the coffee zone and moist hilly regions.

appreciably the same conditions of soil and climate as the *Castilloa*. The tree may live on ground of varied nature and constitution, but it does not succeed well except in rich, argillaceous alluvium, on the banks of streams or rivers, where moisture does not degenerate into swamps and marshes, the regular flow of the water through the soil is to a certain extent indispensable, and in countries where the thermometer registers at midday 32° to 35° C. (89·6° to 95° F.), but which never falls below 22° C. (71·6° F.). It is rare in Amazonia to pass ten consecutive days without rain, and every day clouds of mist envelop vegetation. Now, almost parallel climatic conditions are not to be found in the south of Burmah. But there are other essential conditions which did not at first receive the attention which they deserved. The countries where it is proposed to establish a plantation of indiarubber trees ought to be hospitable; iti s necessary that man should be able to live there, and to withstand the fatigue of regular and continuous labour. In those regions which are specially adapted and fitted for the successful growth and development of the *Castilloas*, as well as the *Heveas*, even the Indian native himself cannot establish a fixed domicile; the more reason, therefore, why the civilised colonist should not even dream of doing so. Amazonia and the banks of the San Juan rivers, the most productive of all indiarubber tree countries, are uninhabited. The *seringueiros* alone pass through them during the so-called dry season, wasted by fever, devoured by insects, longing for the day of departure.

Successful acclimatisation of Manihot Glazowii.—Better success attended the attempts to acclimatise the *Ceara* indiarubber plant, the *Manihot Glazowii*, which thrives naturally on stony ground, where, generally, brambles and such-like bushes alone can live. It requires heat, but it can bear a comparatively large amount of drought. Its natural habitat is in the most arid countries of Brazil, where a temperature of 25° to 30° C. (say 77° to 86° F.) reigns. According to experiments made in Ceylon, this indiarubber plant thrives best at an altitude of 1800 metres (say 5904 feet) above the level of the sea, and does not require any very particular soil, and adapts itself admirably to the climatic conditions of its adopted country. It also succeeds equally well on the Indian continent as in Ceylon, and the *Manihot* was at one time considered as the indiarubber tree of the future.

Aids to germination—Nursery work—Transplanting.—Its seed is very thick, protected by a very hard shell; in order to hasten germination, which lasts for a whole year, the corners may be removed by a file; great care must be taken in this operation so as not to injure the germ. Each seed prepared in this way is planted in the ground; planting is done in the open air, 75 millimetres (say 3 inches) between each seed; the seed is covered with from 12 to 13 millimetres (say about half an inch) of soil, and is afterwards watered twice a day in dry weather. It is essential that the seed be not in the shade, otherwise it will rot. The plants germinate in about three or four weeks; and as soon as the young shoots have attained a height of 30 centimetres (say 1 foot), they are fit for being transplanted out definitely, without any other precaution than to keep the shoots 3½ metres (say 11·48 feet) apart in every direction.

Steeping versus *filing the seeds—Propagation.*—Instead of filing the seeds, an operation always attended with great risk, the planter may rest satisfied with steeping them in cold water beforehand for six days; in that case germination does not commence until the fourth week. Propagation may also be effected by the *marcotage* or *layering* of the young branches; these *marcots* easily take root, provided one "eye" is at least in the ground and another in the open air. At the present time horticulturists and seed merchants supply both shoots in cases and prepared seeds at very moderate charges.

When Manihots can first be bled.—In these unprecedented trials, practice alone could serve as a guide. One of the most important results attained was the knowledge of when to fix exactly the proper age at which to bleed the *manihot*. Experience taught that it was in the fifth year that the first profitable incision

could be made, and that after that the tree could be operated on twice annually, and during three consecutive days each time. The following data relate to indiarubber culture on Cocowate Station, Lunugalla, Ceylon :—

Area under cultivation.—Twelve hectares; say 30 acres.

Duration of "fall of the leaf" period.—Growth stops in a regular manner every year during the months of June and July; the leaves fall and seem to die. But a little afterwards the buds and the foliage reappear more beautiful than ever.

Seeds.—After three years the trees commence to flower and to yield seed, which, as they ripen, fall on the gronnd and germinate rapidly.

Crop.—The trees, still very young, yield but very little, about 500 grammes (say $1\frac{1}{10}$ lb.), but it is more than probable that with age the yield will become more considerable. Experience alone will tell. If, however, this figure becomes a definite one, a hectare will produce annually 375 kilogrammes of indiarubber (say 334 lbs. per acre), which, at the price of 5 francs the kilogramme (say 1s. 10d. the lb.), would give a total of 1875 francs (say £75 the hectare, £30 per acre), the third of which, 625 francs the hectare (say £10 the acre), would cover working expenses, to yield a gross profit of 1250 francs the hectare (say £20 the acre). But unfortunately the Ceylon results have been disappointing; the utmost profit realised was 50 rupees per acre after six years.

TABLE VII.—SHOWING RATE OF GROWTH AND DEVELOPMENT OF *MANIHOT GLAZOWII* DURING FIRST FIVE YEARS

Age in Years.	Height of the Trunk.		Height of Trunk to First Branch.		Circumference at the Base.		Upper Circumference at 2 metres (6½ feet).	
	In metres.	In feet.	In metres.	In feet.	In metres.	In inches.	In metres.	In inches.
1	5·5	18	...	...	0·24	9½	0·17	6½
2	8·25	17	2·50	8	0·56	22	0·35	13¾
3	11·0	35	2·75	9	0·75	29½	0·60	23½
4	13·0	42	3·30	11	1·06	41½	0·62	24⅜ [1]
5	15·0	50	6·70	22	1·16	45½	...	...

Growth is rapid, reproduction by sowing easy as seed-crop is abundant.

French Colonial enterprise—Sluggish ancient methods contrasted with energetic modern measures.—Attempts at acclimatisation and rational culture have also been made in other countries, and especially in the French possessions. If Jacques Duval could say in his day that "Of the five nations which divide equatorial America, it must be acknowledged that France is the one which has made the greatest blunders in its administration of its conquered territory, and, after the lapse of three centuries, our work in Guiana may be thrown in our face as an insult and an injury," he would not be able to speak in this way of our recent colonies in Western Africa, Cochin-China, Tonkin, and Annam. Colonial administration in these cases has been organised on a more practical basis, our administrators interest themselves much more in the working and development of the natural richness of the provinces over which they rule, our explorers, our colonists, our merchants find help, encouragement, and facilities; even our soldiers and sailors understand better, that the conqueror of modern society is useless unless civilisation come alongside of him, charged with finding new commercial and industrial outlets for the mother country as well as for the new colony.

Acclimatisation in the French Congo.—Thus in the Congo, the natives having resorted to cutting down the indiarubber vines instead of bleeding them more or less methodically, the rubber-producing tree, the *Landolphia*, disappeared more

[1] At the level of the branches.

and more every day from the skirts of the coast and the naval stations, and this disappearance thus deprived the immense territory of the coast zone of a considerable source of revenue.

The Libreville Botanical Gardens.—E. Pierre, founder of the Libreville experimental gardens, sought a remedy for the evil in acclimatisation, and in the same way as in Ceylon he has experimented with the *Manihot* (see Fig. 4). The attempts of Pierre are on the road to success; his communication to the Paris Society of Commercial Geography bears witness to it: "A single tree which I imported in 1887 at first yielded 115 trees, of which the greater number now have trunks of 50 centimetres (say 20 inches) in circumference, and a height of 7 to 8 metres (22·96 to 26·24 feet). The tree which M. de Brazza distributes as much as he can amongst the natives has a great future before it in this country. The tree imported in 1887 is the father of 14,000 to 15,000 young plants formed this year. Several thousands of these young seedlings have been distributed to the most distant Pahouins of the river Congo." The director of the Libreville Botanical Gardens counts on being able to supply henceforth 200,000 shoots, which will enable new plantations to be made. But one fact must be pointed out, which has been communicated to us verbally by M. Mazier, one of the young and bold French colonists who settled some years ago at N'Djolé, on the Ogooue:[1]—It is all very well to distribute young shoots of *Manihot* to the Pahouins with recommendations and instructions for their plantation and culture, but the natives, who can only recognise their immediate interests and benefits, have, in the majority of cases, placed the young shoots on one side, to continue, far from any surveillance, their barbarous process of destruction and devastation. By penetrating a little into the interior they find an easy and abundant harvest: what is the good, therefore, of them setting themselves to the weary work of plantation and cultivation, and wait several years for a harvest from which probably they might not profit? The wants of the case are not met, therefore, by simply forming nurseries of excellent indiarubber trees, and distributing the young trees without discernment to the native; it is necessary, if the firm resolve has been made to attain a practical result, that the more intelligent, the more farseeing colonist of the future should see to the surveillance of the plantations, from which he will soon be able to draw substantial profit. According to Paroisse, the Libreville *Manihot* is not the same as that which yields the Ceara and the Ceylon *Manihot*, but a *Manihot* which is a native of one of the isles in the neighbourhood of the French colony *des rivières du Sud.*[1]

Acclimatisation in Cochin-China.—In Cochin-China, where the soil and the climate are admirably adapted for indiarubber plantations, acclimatisation experiments have not been neglected. M. Pierre, the director of the botanical garden of Saïgon, has successfully acclimatised the *Hevea guyanensis.* It is not known whether the transplanting into fresh ground has succeeded any better than the Kew trials.

In Reunion.—The Isle of Reunion has also had its attempts at the acclimatisation and rational culture of indiarubber. Unfortunately no information as to the success of these attempts is available.

Rational culture in South America.—Peru, Colombia, Costa Rica, San Carlos, and Amazonia itself, have all had their attempts at the rational culture of rubber,

[1] At the time at which this article is being finished, it would appear that the question of the rational culture of the Ceara indiarubber had received a check at the Congo. Fortunately this check was not of long duration, for the following is what we read, under date of 19th August 1894, in the different Paris newspapers:—"The *Journal Officiel du Congo*, which reached Paris to-day, publishes a report of the director of the Libreville Botanical Garden, from which it would appear that the trials on the germination of the Ceara (?) indiarubber, commenced a long time ago, have finally been crowned with complete success. After many blindfold attempts, a process has been discovered, by means of which, after a simple and practical preparation, these seeds placed in the ground and watered spring up in eight days. At the present time the garden possesses about 1000 of these small plants, which, in a little, may be handed over to the planters." Are the seeds sown the same way as those in Ceylon? We do not know (Authors' note to first edition).

and the result has always responded to the sum of the efforts expended. But let it be well known, and here the authors speak more especially for the benefit of *compatriots*, that experimenting alone is not all that is wanted; it is necessary, like the British, to persevere and not to be discouraged with a first failure, nor by the first unproductive expense. If success be certain, it is possible to wait a little longer. Every experiment always yields a result, but this result may not be attained until the moment when the operator has already lost all hope. What more striking proof could be given of the truth of this remark than Goodyear in despair and reduced to his last extremity, who finally discovered the vulcanisation of indiarubber, and afterwards the manufacture of ebonite or hardened indiarubber!

But France is now doing excellent work in rubber cultivation in West Africa, and there are hopes of Madagascar being opened up for rubber cultivation also.—[TR. 1909.]

Tapping plantation rubber trees.—The planter decides upon the form of cuts he

FIG. 21.—Collecting rubber by spiral tapping in British Malaya.

will adopt—herring bone, V-shaped, spiral, etc.—the first two being practically the only ones adopted in Malaya. The bark is cut across the tree in the selected way, but not so deeply as to reach the wood of the tree, always leaving behind some of the cambial, or growing layer of the stem, so that the wound may rapidly heal and before very long be suitable for tapping over again.

Directly the cut is made, the milk-white latex, which is a mixture of caoutchouc, or rubber, and the sap of the tree, flows, and where there are a number of cuts of a tree these are joined together by shallow channels in the bark, and the latex runs down to a round aluminium or galvanised iron cup placed at the base of the tree. As much as half a pint of this white milk-like fluid may run into the cup, and then the flow ceases and some of the latex begins to coagulate on the cuts and in the channels on the tree, from whence it is pulled off and, after thoroughly cleaning, becomes "scrap" rubber, which differs only slightly in colour from the rubber prepared from the latex caught in the cups. A series of experimental tappings were

recently made upon *Castilloa* trees of six, seven, and eight years old, on an estate on the Isthmus of Tehuantepec. The crude method of tapping as practised by the native Indian, by cutting the trees with a "machète," has, of course, been super-

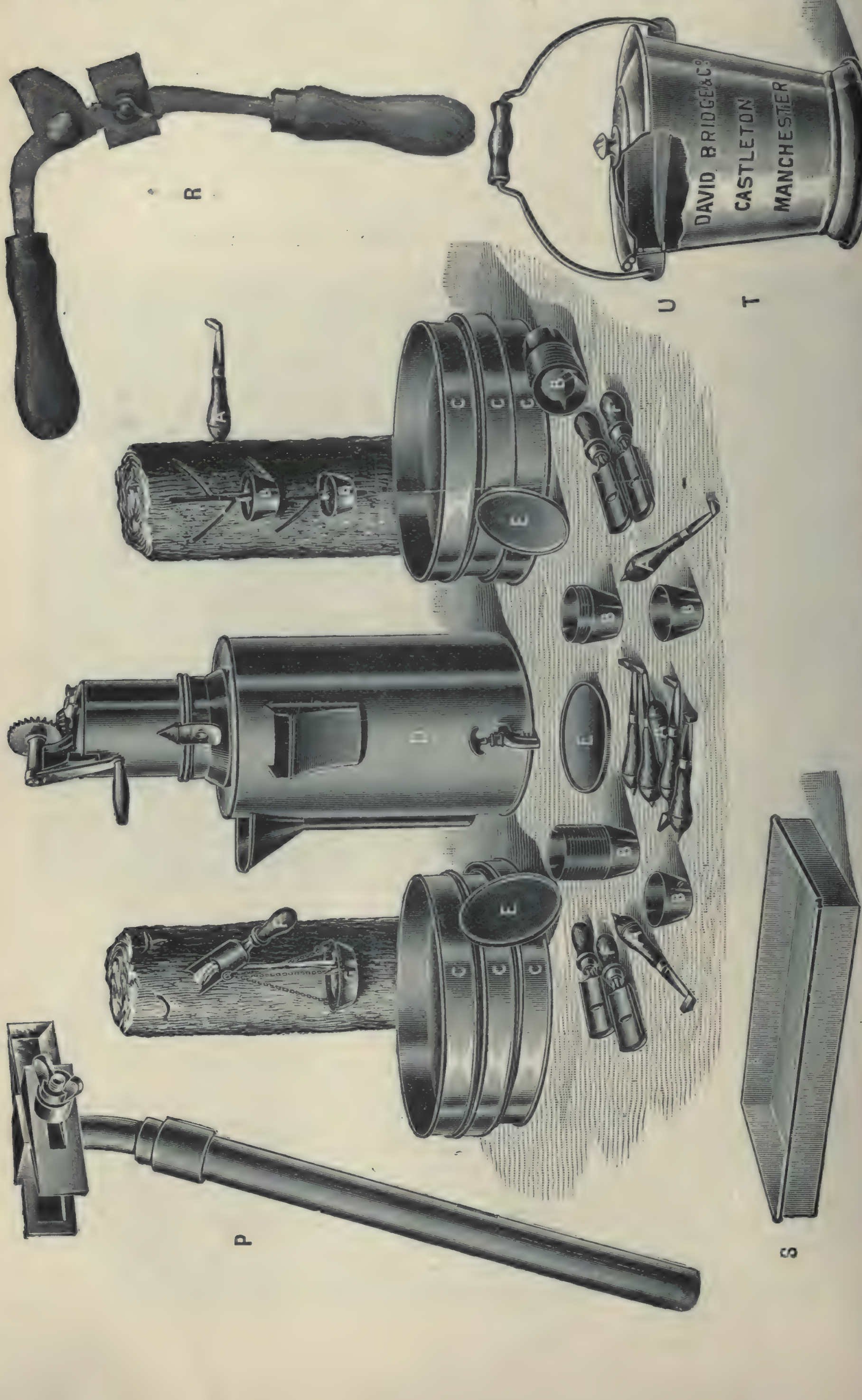


FIG. 22.—Utensils and tools used on a rubber plantation.

seded by the employment of specially designed tools. The knife used in the experiments here dealt with was one invented by Mr. V. S. Smith, an American planter in the State of Chiapas. The incisions were made in V form, but, instead of making a complete V, the cut on one side was stopped short of the other, to avoid introducing a possible focus of infection or rot at the meeting-point, where moisture might be retained. A drip cup was attached to the base of the tree, by means of an upward cut made in the bark, the bottom of the cup resting on the ground. (The object of the *upward* cut was, of course, to convey the latex into the receptacle without waste.) In earlier tapping experiments a straight incision was also made between the centres of the V's, forming a regular herring-bone arrangement; this was, however, found to be a useless mutilation of the cortex,

FIG. 23.—Collecting rubber from *Castilloa* trees by **V** tapping in a Mexican plantation.

increasing the risk of rot, as the mere drawing of a finger on the bark from V to V sufficed to establish a route for the flow of the latex down into the drip cup. The central cut, moreover, added little or nothing to the actual flow of latex, owing to the vertical structure of the lactiferous cells in the *Castilloa* tree. When the higher parts of old trees are tapped, the latex obtained is often changed in constitution. The latex from high parts is often very watery, and possesses a low percentage of caoutchouc; on treatment with the requisite quantity of acid, coagulation does not take place; even when allowed to stand for several days a curdled liquid only is obtained, the particles of which are not elastic and do not adhere to one onother.

The number of times when non-coagulable Para latex has been obtained from various sections of the stem of twenty-nine-year-old trees is given below, and in considering them it should be remembered that the circumference of the stems at the higher points tapped was not less than 30 inches.

TABLE VIII.—PERCENTAGE OF TAPPING GIVING NON-COAGULABLE LATEX.

Height of tapping area.	Number of times tapped.	Number of times when latex not coagulable.	Per cent. of tappings giving non-coagulable latex.
Base to 5 or 6 feet . .	1165	9	0·77
,, 6 to 16 feet . .	95	1	1·05
,, 10 to 20 ,, . .	94	1	1·06
,, 20 to 30 ,, . .	94	2	2·12
,, 30 ,, . .	171	24	14·03
,, 50 ,, . .	84	5	5·95

Coagulating plantation latex.—The latex may be transferred to the factory in suitable vessels carried by the coolies on their head, or it may be transferred to the factory in capacious milk cans on trucks running on a mono-rail. At the factory it is run into either circular or rectangular small tins, and treated with the requisite amount of lime juice, acetic acid, formic acid, etc. When the rubber is not washed it assumes the form of the vessel in which it was coagulated, namely, round biscuits or rectangular sheets. When large quantities are coagulated in bulk, after being treated with the calculated amount of acid, the whole is allowed to stand till next morning.

Dittmar's classification of coagulants.—Amongst chemical coagulants not mentioned in the text by the original authors in the first edition, Dittmar in his classification of coagulants gives the following :—phenicin sulphate, acetone, acetic acid, formic acid. He also gives a separate heading to coagulation by urine, and another to coagulation by sterilisation followed by acidification, amongst which he enumerates the following antiseptics as being used—formaldehyde, guaiacol or thymol solution, then acidification with oxalic acid, formic acid, citric acid, extract of termites and of ants. In addition to churning, he gives a separate heading to centrifuging, otherwise his classification is similar to the authors'. Zimmerman classifies the reagents he used or tested for coagulation of the latex of *Manihot-Glaziowii* as follows :—

Useless—Alum, 5 per cent. ; ammonium ferrocyanide, 5 per cent. *Incomplete or very slow*—formalin, 2 per cent. ; common salt, 2 to 5 per cent. ; pyridine, 2 to 4 per cent. *Paplike*—Tannic acid, 2 to 5 per cent., and bark extract from *Acacia decurrens*. *Good*—hydrochloric acid, sulphuric acid, formic acid, acetic acid, citric acid, lysol and carbolic acid.

Weber's summary of coagulation according to his theories.—(1) That the so-called coagulation of rubber by acids or alkalies is erroneous in that it is only the albumen which is coagulated by these substances, and not the rubber itself. (2) That the albumen contained in latex is very harmful in many respects, and that it ought to be as far as possible eliminated from the milk before attempting to agglutinate the rubber. (3) The method Weber recommends for coagulation is briefly as follows :—First mix the latex with water at least five times its volume. In cases where the latex is thick, actual boiling water may be used with advantage. In this state it can be easily strained to remove impurities. After this, add formaldehyde in the proportion of 8 oz. to a petroleum barrel, stir well and let it stand for twenty-four hours, when the rubber will collect on the top and can be lifted out in one mass. In order to remove any traces of albumen that may be suspended, the rubber should next be cut into strips and subjected to a thorough washing upon an ordinary rubber washing machine. But, according to Watt, the use of formaldehyde does not seem to have been the success that Weber anticipated, though his recommendation for cleanliness and repeated washing has been universally accepted.

Weber regards *coalescence* of the latex as in the churning process as different

from *coagulation* thereof. The latex examined by Harries he asserts had nothing in common with good latex. To Weber there is the same difference as between butter-making and cheese-making. In the future, when we know how rubber becomes polymerised, a more decided opinion can be formed on the subject. The direction which the polymerisation assumes plays an important rôle in the process, and Weber doubted if Esch and Chvolles well understand its bearing. One cannot, in Weber's opinion, regard the polymerisation of rubber like that of other organic bodies, such as formaldehyde into paraldehyde, acetylene into benzene. Besides, coagulated rubber has not the same properties as coalesced rubber; that is why the centrifugal method used in Ceylon failed to give good results, the products obtained thereby not being comparable with the rubber obtained by coagulation by means of acetic acid. The coalesced product has no sale on the market, because it is especially in the *Hevea* latex exploited in Ceylon that the differentiation of the two products is very decided. Weber attributed that to a less advanced stage of polymerisation in the coalesced product, but he was never able to impart to it the polymerisation of the coagulated product. Then, again, there is another thing besides polymerisation in rubber. Rubber has a structure, for its physical properties are sometimes different according to the direction, thus one can easily detect sometimes that rubber vulcanised in sheets has an elongation in the case of overcured rubber in one direction and undercured in another. Weber made experiments fourteen years ago (*i.e.* in 1891) in Messrs. Macintosh's factory in Manchester, in order to dissolve fine select Para rubber in ether, and found to his great astonishment that sheets of this quality did not dissolve therein even after several weeks' contact. Weber afterwards, with his assistant, Mr. Betteridge, frequently repeated this experiment, and the result was always the same. Weber also repeated the same experiments on other rubbers, but his death prevents an account of them being given.

According to Weber, there are considerable oscillations in the solubility of rubber in ether. Carbon disulphide solves the problem better. It may be taken that the portion which dissolves in ether is pure rubber of the formula $C_{10}H_{16}$, and that the remainder obtained by other solvents contains oxygen of which the quantity gradually increases with the fractionation, and the rolls change the ratio of these two quantities and may render all the rubber solvents. That plays a grand rôle in actual practical working, and Weber had said so for a long time. We cannot, therefore, appreciate the quality of a rubber by the amount of insoluble, it being given that mixing and mastication changes this very variable quantity even so far as to cause it to disappear altogether.

The churning and centrifugal methods of coalescing the latex.—Biffen, by treating the latex in a centrifugal,[1] revolving at a speed of 6000 turns a minute, found that the *Hevea* latex left a residue of 28 to 30 per cent., and that of *Castilloa elastica* 25 per cent. The latex, after being mixed with 50 per cent. of water, is placed in the machine and spun for the space of a few minutes. The machine is then allowed to come to rest gradually, when the rubber floats to the top of the liquid in a thick white mass, with the albumenoids, proteids, and all dirt and chips at the bottom. The rubber is skimmed off and drained on a porous surface. According to experiments carried on by Mr. Hart in Trinidad, it can be removed in about two hours, and in six hours afterwards it is comparatively dry. The advantages claimed for this method of extracting caoutchouc are as follows: (1) It produces absolutely pure rubber; (2) the whole process is under scientific control; (3) it is capable of dealing efficiently and immediately with any quantity. Many recent writers deprecate the use of centrifugal force, and special machinery has been patented in which the advantage set forth is that they do not invoke the aid of that force.

The noxious enzyme in rubber latex.—Preyer churned the soft milky cream in a boiling aqueous solution of formic acid or chloral hydrate, and obtained rubber of a pure white colour, and it remained white in the air, and when well washed with

[1] Watson, Laidlaw, & Co. type.

water contained neither resinous nor acetic compounds. The colour of rubber would therefore appear to be due to oxydases. With regard to the important discovery by Bamber of the enzyme which occurs in rubber latex, and which, if not destroyed early in the preparation of the raw rubber by heat or by washing, tends, with other organic products, to darken the rubber when it is exposed to the air. Bamber states that unless this enzyme is destroyed, the sunlight through a window or crevice falling on parts of the rubber, or a draught of air, tends to turn out a batch of rubber uneven in colour, according to the varying amount of the enzyme present. It is advisable to ensure the destruction of the enzyme which occurs in the

Fig. 24.—The K. L. [Kala Lumpur] Coagulator.

latex, together with certain organic products which darken on exposure to air. The enzyme has an effect very similar to the enzyme in tea. Unless it is destroyed early in rubber manufacture, or thoroughly removed by washing, variations in colour are bound to result in every day's out-turn, as it is impossible, under present estate factory conditions, to dry all the rubber under identical conditions of light, air currents, and probably temperature. The sunlight through a window or crevice falling on parts of the rubber and not on other parts, or a draught of air, would tend to darken the colour, but the change would also be affected by the varying amount of enzyme present. The strength of the rubber is probably not affected, or only to a very slight extent, by this variation in colour, but a pale

rubber is preferred for many superior articles, especially articles for medical use. The best feeding-bottle tubes and teats are no longer black or opaque, but transparent and of a pale yellow, which is a great safeguard against uncleanliness.

Early in 1907, Bamber filtered latex through porcelain in a vacuum, and obtained the perfectly colourless watery part of the latex containing all the soluble matter naturally present. On exposing this liquid to air, he noticed that within a few minutes a rapid darkening took place, which pointed to the presence of an active oxydising enzyme, and this he confirmed by other tests. It was evident that, if this enzyme could be destroyed, or removed together with most of the soluble matter, paler rubber should result. Experiments showed the temperature at which the enzyme could be destroyed, and it only remained to get experiments made on a large scale, on some estates for which arrangements were made before

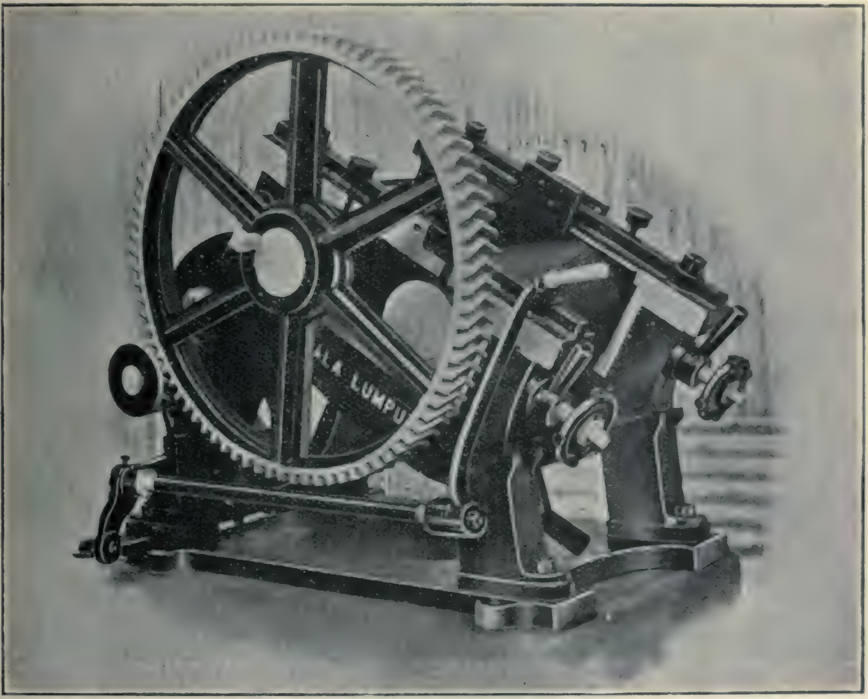


FIG. 25.—Plantation rubber washing machine, constructed in Kala Lumpur, Federated Malay States.

Bamber left for England. Rubber so treated has obtained the top price at several recent sales, and the fact has attracted considerable attention. The heat must be applied long enough to thoroughly penetrate a non-conducting material, for the mere surface destruction of the enzyme is useless.

Washing plantation rubber by a Colonial constructed washing (or rolling) machine.—This new machine, Figs. 25, 26, has been produced primarily for large estates, and is of a similar size to a washing machine manufactured in Europe. It can be converted into a rubber rolling machine when desired.

Plantation block rubber.—Fig. 27 shows a new and improved form of machine for compressing washed rubber into blocks for shipment. It is entirely self-contained, requiring no belting nor shafting for driving, is easily worked by native labour, and has no complicated parts likely to get out of order. The twin

boxes into which the rubber is placed are 9 inches square by 8 inches deep, and finished blocks 9 inches square by about 3 inches thick are obtained after the pressure has been applied. The top of each box is hinged to facilitate charging and emptying, and is held in position by a simple locking device when the pressure is on. The pressure is obtained by a small hand-pump, capable of exerting

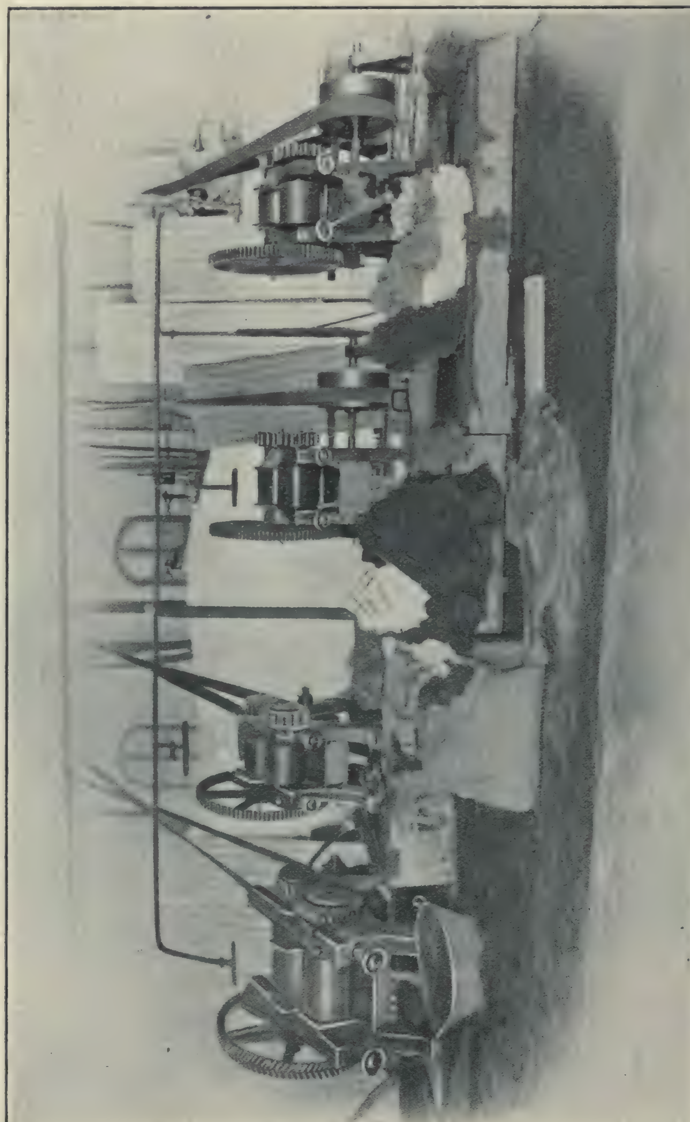


FIG. 26.—Testing rubber washing machines before delivery in the maker's workshops at Kala Lumpur in the Federated Malay States.

a pressure of 7 tons on each ram. The presses and pump are carried on a cast-iron box base which forms a water tank, from which the water is obtained for working, and after each operation the water is again returned to the tank. The valves are arranged to enable each press to be worked separately, so that while one press is being charged the other can be pressed and emptied, thus reducing the labour to a minimum. Loose plates are provided to fit inside the boxes, by means of which

the name, quality, or other distinguishing marks can be impressed on each block. Single presses are also made on similar principles to the above, also presses of any other size to suit individual requirements.

The usual method of drying rubber is by means of hot air, passed through drying rooms by means of fans or similar devices. Certain drawbacks attached to the drying methods at present used have led to a very general use of a vacuum in the place of hot air, with satisfactory results, and among the most suitable vacuum apparatus, with condensers and vacuum pumps, are those of the Emil Passburg System (Fig. 28).

For the Scott method of drying rubber the following advantages are claimed: Rapid drying at low temperatures. Extreme economy of steam, practically all the heat in the steam being utilised in removing the moisture from the substance.

Fig. 27.—Hydraulic rubber blocking press, with two boxes and hand-pump.

Small space occupied. Freedom from atmospheric impurities. Uniformity of working and uniformity of product. Independence of climatic conditions. Rubber can be dried in from one to four hours. Temperatures from 90° F. upwards, and below this, if required, the rate of drying then being slower. The Scott stove is used for drying rubber in crepe, block, biscuit, worm, or manufactured form, and gutta percha with recovery of solvent. It can be supplied in cast-iron or mild steel body of either rectangular or cylindrical form; also made in sections for easy transport and up-country work. Other features are—Shelves constructed in one piece without any joints. Special method of attachment with steam joint outside the stove. Door of sliding or hinged form to suit requirements and position. Condenser of double-flow type, giving complete condensation with economy of water. Receiver fitted with inspection glasses, enabling the flow of condensed water and

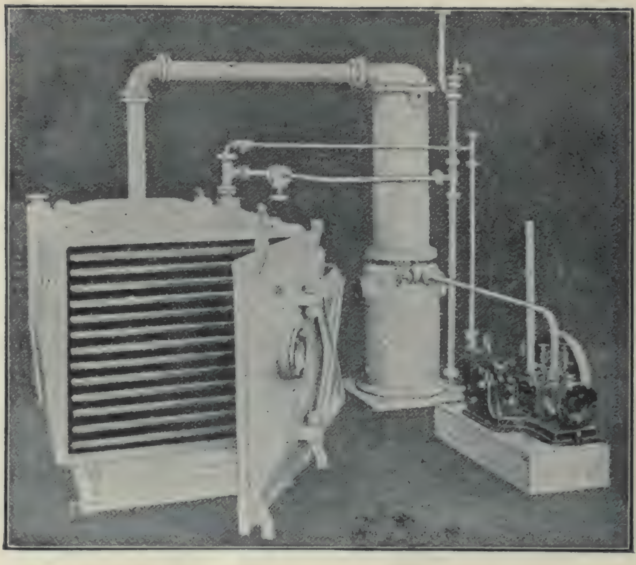


Fig. 28.—Vacuum dryer for indiarubber (Passburg).

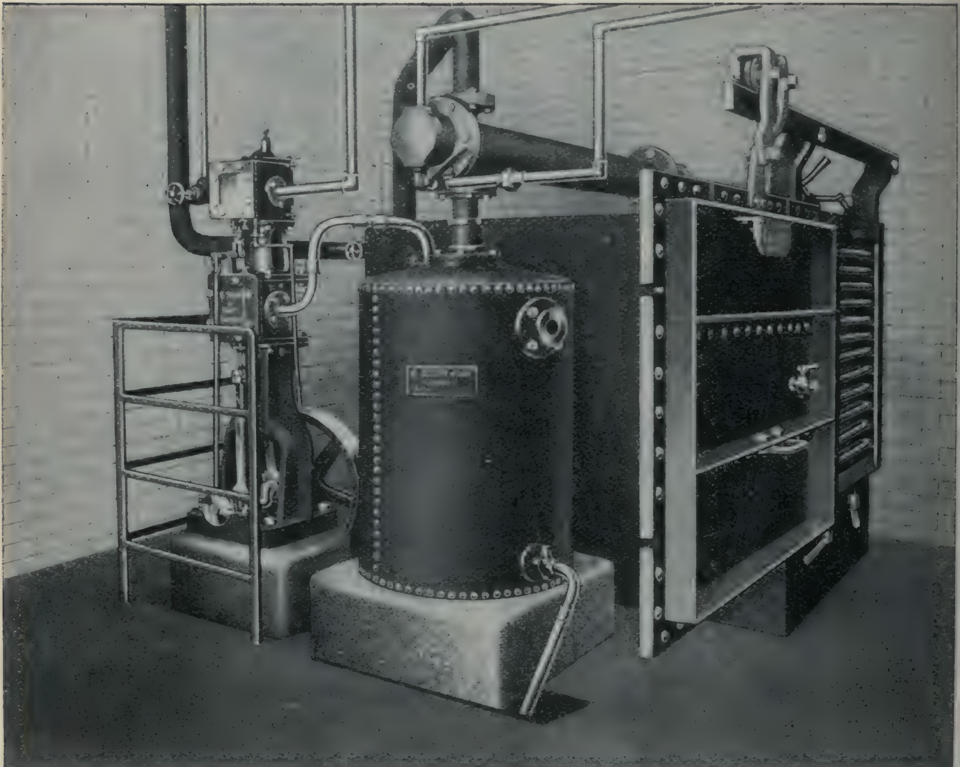


Fig. 29.—Vacuum dryer for indiarubber (G. Scott & Sons).
(See right-hand corner of plan, Fig. 30.)

(by inference) the condition of the drying operation to be determined Vacuum pump with mechanically-moved valves requiring little attention or repair, supplied

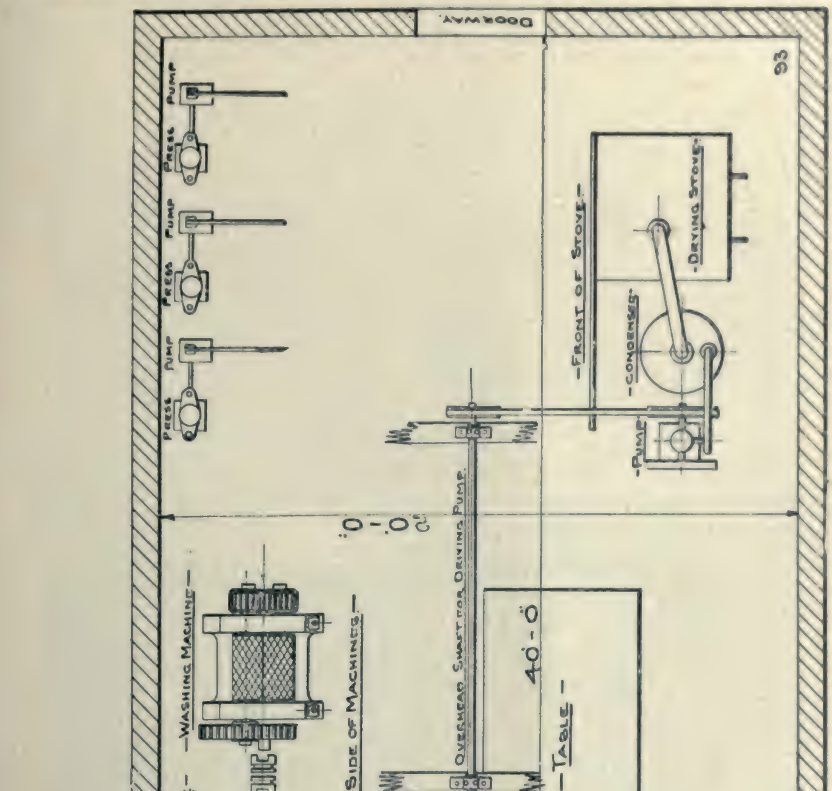


Fig. 30.—Plan of plantation rubber factory as fitted up by Francis Shaw & Co., Manchester.

either steam or belt driven. The plant is made in standard sizes, which meet the ordinary requirements. Many larger sizes have, however, been constructed, and

special combinations of plant with a number of stoves working into the one condenser have also been made.

Recent development in rubber arboriculture.—Since the above critical essay on rubber acclimatisation was written by the original authors of this treatise, the whole domain of the arboriculture of rubber has widened and enlarged, and the tropical culture of indiarubber in equatorial zones has progressed to an extent which at that time no one then dreamt of its attaining within such a short period of time. The contentions of the authors in this chapter that the *Hevea* cannot be acclimatised in the East, etc., so as to produce rubber at a profit, seem to have been

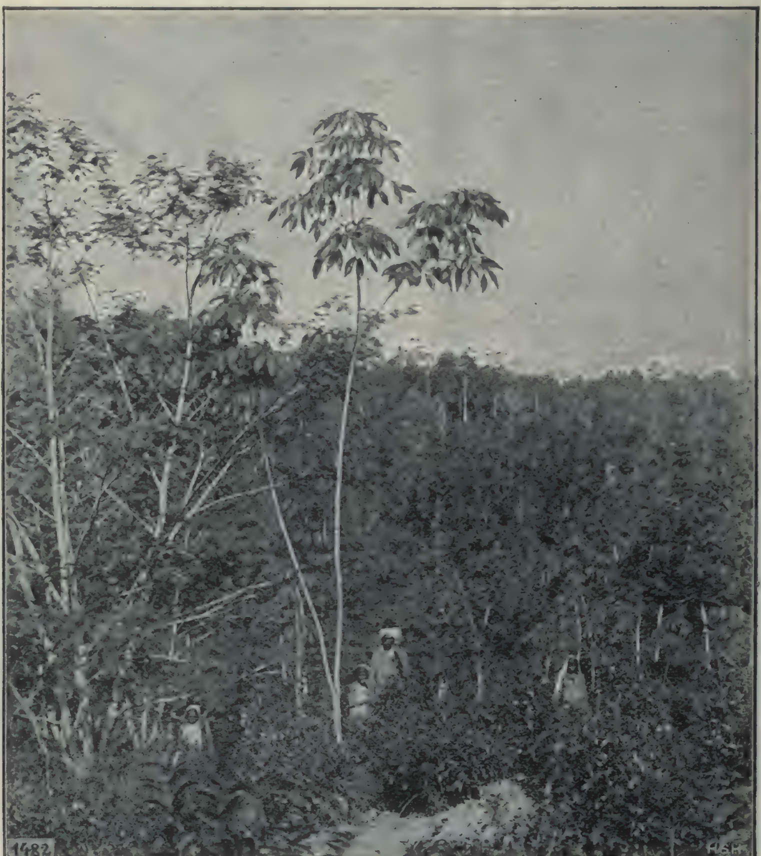


FIG. 31.—Rubber plantation three years old. Strong application of potash (15 per cent.); weak application of nitrogen (4·5 per cent.). Circumference of stem 1 inch from base: beginning of 1905, 9 inches; June 1906, 14 inches.

demonstrated by actual results to be untenable. Their ideas are, however, worthy of respect, and there can be no doubt but that the *Hevea* yields a more abundant and a better quality of latex in its own hemisphere, in its own native habitat on the banks of the Amazon and its tributaries, than in a colonial plantation in another hemisphere. But that is not to say that it cannot be cultivated at a profit in such colonial plantations. On the other hand, many other authorities besides the authors question the advisability of replacing native rubber by *Hevea*, etc.

The function of fertilisers in rubber culture.—Let us deal with the question of fertilisers in rubber arboriculture, and then we shall be free to consider the

opinions of different observers in all their bearings. Up to now artificial manures have not been very largely used in the rubber arboriculture, but this practice is now coming more into favour. This is due to the results of many experiments, which have shown the following advantages from the judicious use of suitable fertilisers :—(1) There is a *healthier and better growth of the trees*, and this makes

FIG. 32.—Rubber plantation four years old. Too strong application of nitrogen (6 per cent.); too weak application of potash (5 per cent.). Circumference of stem 1 inch from base: beginning of 1905, 9½ inches; June 1906, 13 inches.

it available to commence tapping earlier, and the trees are more resistant to the attacks of diseases and blight. (2) The trees grown on cultivated and manured land give a *greater increase of growth* each year, and this increases the amount of tapping that can be carried out. (3) There is a *quicker and more thorough renewal of bark*, and as a result a *larger yield of rubber* per annum. (4) *An*

increased and more regular flow of latex. (5) *The growth and vitality of the root system is considerably developed.* This result is of very great importance in the drier zones, as the deeper and more widely spread the root system is carried, the smaller the chance of the tree being affected by drought, and the more unvarying the latex return during the drier seasons of the year. For the above reasons, the application of artificial manures to rubber trees in bearing is an economical and necessary practice for their successful and permanent cultivation. In most countries artificial manures are obtained at a comparatively small cost, which is much more than repaid by the good results previously mentioned on the yield and growth of trees. In some countries rubber plantations are found on rich virgin soils, but, nevertheless, in many cases the application of artificial manures is found to have a very well-marked and valuable effect. In other parts rubber plantations are found on very poor soils, and in these cases there is no question at all as to the value of applying artificial manures. The same may also be said of rubber growing among tea. Here the artificials have a double effect, for whilst improving the growth and yield of rubber they also improve the quality and increase the yield of tea; on lands where tea is growing, a larger application of manures can be given than on land only carrying rubber trees, as the ground is more thickly covered with plant life. The question that now comes to the front is, What manures should be applied? But we may first state that the three most required plant foods deficient in the soil are *nitrogen*, *phosphates*, and *potash*, and it should be the method of all cultivators of rubber to apply these three plant food constituents in the manure that is applied, and also to give them in the proper proportions that the plants require. Let us take a survey of the three most essential plant foods, and commence with the one that requires the most care in its judicious use. The application of too much nitrogen tends to make the plants produce very quick growth, and this causes the trees to become very weak and tender and very liable to be broken down by the wind, as shown in Fig. 32.

The result of an experiment on the manuring of rubber trees in Ceylon, which was carried out by Mr. R. M. Eckert, Vincit, Ruanwella, showed the good effect of a rational manuring, which consisted of—

Table IX.—Showing Ingredients of Rational Manure for a Rubber Plantation and the Chemical Composition of the Mixture.

Ingredients.	Chemical Composition.		
	Potash.	Phosphoric Acid.	Nitrogen.
20 per cent. Castor cake, 10 ,, Rape cake	...	...	1·8
10 ,, Crushed fish	...	0·4	0·6
10 ,, Bloodmeal	...	0·1	1·3
20 ,, Bonemeal	...	4·0	0·8
30 ,, Muriate of potash	15	...	...
100 ,, contains	15	4·5	4·5

This gives a well-balanced manure, which produces a very healthy plant. But quite a different result ensues from injudicious manuring in a case of a tree manured by a mixture containing—

TABLE X.—SHOWING THE COMPOSITION OF A DEFECTIVE MANURE FOR A RUBBER PLANTATION, WITH CHEMICAL COMPOSITION OF THE INGREDIENTS AND OF THE MIXTURE.

Ingredients.	Chemical Composition.		
	Potash.	Phosphoric Acid.	Nitrogen.
25 per cent. Castor cake }	...	...	2·4
15 ,, Rape cake } . .			
20 ,, Crushed fish . .	...	0·8	1·2
10 ,, Bloodmeal . . .	...	0·1	1·3
20 ,, Bonemeal . . .	...	4·0	0·8
10 ,, Muriate of potash .	5	...	...
100 ,, contains . . .	5	4·9	5·7

This mixture contains a higher percentage of nitrogen and a lower percentage of potash, with the result that the tree is in a very weak-wooded condition, the stem being much bent owing to the growth of a heavy top with too much leaf-growth. But the result of this experiment was further demonstrated in 1906, when the same characteristics were shown. When the rubber trees are manured with mixtures containing a large percentage of potash and a small percentage of nitrogen, the trees are all in a good, healthy condition, whilst the result of the application of manure containing a large percentage of nitrogen and a small percentage of potash is that the tree has been broken down by the wind and thus destroyed, owing to the tenderness of the wood, due to the too strong application of nitrogen and the too weak application of potash (Fig. 32). The above gives a good illustration of the effect of a too high proportion of nitrogen; but, nevertheless, nitrogen cannot be allowed out of a manurial mixture, as the potash, phosphoric acid, and *lime* without nitrogen do not appear to have their full effect, owing to the deficient leaf-growth of the tree. Phosphoric acid is also essential in a manurial mixture, as it is found to be beneficial in not allowing an excess of leaf-growth, but potash appears to hold the most important relation to the rate of growth of the trunk and branches, provided it is accompanied with sufficient supplies of phosphoric acid and lime, and a reasonable quantity of nitrogen to induce free growth and the absorption of the three inorganic ingredients above mentioned. Now comes the question of the form

TABLE XI.—FORMULA FOR MANURE FOR RUBBER PLANTATION ON LAND RICH IN NITROGEN AND GOOD LEAF-GROWTH.

Ingredients.	Chemical Composition.		
	Potash.	Phosphoric Acid.	Nitrogen.
28 per cent. Muriate of potash (50)	14	...	...
25 ,, Superphosphate (18) .	...	4·50	...
20 ,, Bonemeal (28/1) .	...	5·60	0·2
17 ,, Oilcake	...	...	1·3
10 ,, Sulphate ammonia .	...	...	1·6
100 ,, contains . . .	14	10·1	3·1

400 to 800 lb. per acre to be applied.

in which the manures should be employed. Nitrogen can be employed in the organic form as fish guano, bloodmeal or oil cake, or inorganic as sulphate of ammonia.

Phosphoric acid can be employed in various forms, such as superphosphate or basic slag, but on soils that are deficient in organic matter bones are useful. Potash may be employed in the form of muriate or sulphate, and in many cases muriate seems to have the best results in the dry climates. The mixture given in Table XI. is suitable on land rich in nitrogen and where there is a good leaf-growth; moreover, the superphosphate supplies both lime and sulphuric acid to the soil in addition to phosphoric acid.

On land which is very poor the following mixture is to be recommended:—

Table XII.—Formula for Manure for Rubber Plantation on Poor Land.

Ingredients.		Chemical Composition.		
		Potash.	Phosphoric Acid.	Nitrogen.
20 per cent.	Muriate of potash (50)	10	...	...
30 ,,	Superphosphate (18) .	...	5·4	...
10 ,,	Bonemeal (28/1) .	...	2·8	0·1
24 ,,	Sulphate of ammonia .	...	...	4·9
16 ,,	Oil cake (6) . .	...	...	1·0
100 ,,	contains . . .	10	8·2	6·0

400 to 700 lb. per acre to be applied.

When to apply manures.—The next question is, When is the best time to apply these manures, and the method of applying them? Artificial manures should not be applied during heavy rains or just previous to the rainy season, as if then applied there is considerable loss due to drainage.

Mode of applying manures—Cattle manures.—The manures can be sprinkled round the tree at a distance of from 1 to 1½ feet from the stem for each year of the plant's growth, and then thoroughly forked into the soil, or, in order to secure the manure not being washed away, a shallow trench may be cut round the tree, and the manure forked therein, and the surface soil then replaced. Another point with regard to the manuring of rubber is, there is a very large advantage to be obtained by green manuring, whilst the use of litter and cattle manure is also of the greatest advantage. The cattle manure has a twofold effect, and that is, besides acting as a direct manure, it is also of very great influence in ameliorating the soil, and also the acids which are formed are of great benefit in making the insoluble salts soluble in the soil and thus more readily taken up by the plants. The chief thing to take into consideration about farmyard manure is that in tropical countries it is very scarce, and with the supply available it is best applied to other crops than rubber, and for this crop only to apply artificials, with frequent green manuring.

Green manuring.—The value of green manuring is very great, but the fullest advantage is only obtained by it being supplemented by an application at the time of ploughing in of potash and phosphoric acid. For this purpose the potash is best applied in the form of muriate, and the phosphoric acid either as superphosphate or basic slag.

The following mixture should be employed at the time of green manuring:—

TABLE XIII.—SHOWING COMPOSITION AND ANALYSIS OF CHEMICAL MANURE TO BE APPLIED IN CONJUNCTION WITH GREEN MANURING.

Ingredients.	Chemical Composition.		
	Potash.	Phosphoric Acid.	Nitrogen.
34 per cent. Muriate of potash .	17	...	...
44 ,, Superphosphate . .	...	7·9	...
22 ,, Bonemeal . . .	...	6·2	0·2
100 ,, contains . . .	17	14·1	0·2

Of the above mixture 600 to 900 lb. per acre can be applied.

If the above points are attended to, and a liberal supply of potash, phosphoric acid, and nitrogen given, with periodical applications of green manuring, very successful results and profitable returns can be obtained in the cultivation of rubber. (For further particulars as to plant chemistry and the scientific use of manure, see *Agricultural Chemistry*, by Ingle (Scott, Greenwood, & Son.).)

Rubber plantations in Ceylon.—From an official British Colonial Report for the information of those studying the Ceylon rubber exhibits at the International Rubber Exhibition at Olympia 1908, it appears that—

It was not until 1876 that a commencement was made of Para rubber cultivation in Ceylon. In this year, 2000 seedlings were sent out from Kew to Peradeniya, one of the Ceylon Government's experimental stations. These plants had been raised from seed obtained by Mr. Wickham from South America. At the beginning the plants were first propagated from cuttings, but when they began to flower, and seeds became available, the earlier method was naturally dropped. In 1883, over 200 seedlings were raised from seed obtained from the original plants, and in 1884, about 1000 seedlings were grown, the whole being distributed to planters and officials throughout Ceylon. From the 500 original trees which came to maturity, the seed supply has risen from 200 seeds in 1883, to about 200,000 at the present time. Much of this rubber has been planted throughout tea, and a fair amount of the remainder is interplanted with cocoa and other products. For instance, in the Kalutara district up to the end of 1906 there were about 20,000 acres under rubber; of this, however, only 9000 acres were under rubber alone, the remainder being interplanted with other products, chiefly tea.

Exports of rubber from Ceylon.—The following figures, showing the exports of rubber from Ceylon, are taken from tables complied by the Colombo Chamber of Commerce :—

TABLE XIV.—SHOWING EXPORTS OF RUBBER FROM CEYLON, 1903–1907.

Year.	Lb.	Year.	Lb.
1903 .	41,798	1906 .	327,661
1904 .	77,212	1907 .	556,080
1905 .	168,547	...	...

This crop is, of course, only derived from a very small proportion of the rubber already planted. Taking the age at which a rubber tree can be tapped at six years, it will be seen, on comparison with the figures given on another page, that the

output for 1907 was derived from not more than 4500 acres. The planted area in Ceylon at the present time is almost forty times as large as this, so that in six years it would be safe to put the export at a very much higher figure than the amount given for 1907.

Climatic conditions.—In its native home, the Para tree grows from the sea level up to a fair elevation on the highlands. The rainfall is usually between 80 and 120 inches, and the mean temperature between 76° and 81° F. Although the Para tree has shown itself to be adaptable to a considerable degree, it is only a comparatively limited area of Ceylon that seems to be suitable for its cultivation, as elevation and rainfall has to be taken into account. In a recent Surveyor-General's report it is stated that rubber is being successfully grown under the following conditions :—

TABLE XV.—SHOWING DISTRICT ELEVATION AND RAINFALL UNDER WHICH RUBBER IS BEING SUCCESSFULLY CULTIVATED IN CEYLON.

District.	Elevation.	Rainfall.
Galle	48 feet	91 inches
Kalutara	200 ,,	150 ,,
Passara	2800 ,,	89 ,,

Wright states that in Ceylon an elevation of 2000 feet in the Central Province, and 3000 feet in the Uva Province, is considered near the maximum, and a rainfall of 70 near the minimum, for the cultivation of this species.

The planting of rubber in Ceylon.—The following are a few brief notes on the planting operations in connection with rubber cultivation :—The forest is cut down, and when dry is burned. Drains are then cut, the number and distance depending upon the land. Holes are then dug, 1½ feet deep by 2 feet by 2 feet being considered good, the axiom being that the larger the hole the better the plant, the plant responding to generous treatment. The distance between the holes depends upon the planter's idea of wide or close planting. Para trees are grown in Ceylon from 10 feet by 70 feet to 20 feet by 20 feet. The average, however, is about 180 trees to the acre. The seeds are either planted out as soon as they have germinated in the nursery, or they are allowed to grow there until they have attained a fair size, and become what are known as stumps. A still better method is to grow the seeds in a rough basket in the nursery. When the time for planting-out comes, the basket is put in the hole with the seed, and there is thus no interruption of root growth. Planting-out operations should, of course, only be conducted when rain is plentiful. As a general rule, all planted rubber is fenced in order to protect it from the attacks of animals. As soon as the rubber is planted, the planter's main duties are to see that any vacancies are supplied, and to keep the ground free from weeds, which would interfere with the growth of the young rubber. Weeding is a comparatively expensive operation, and many planters prefer to reduce the expense by the cultivation of some other product between the lines of the rubber trees. In most districts where the cultivation of cocoa is possible, this product is the favourite, as not only is it profitable, but it seems to last for a much longer time when the shade of the rubber has grown dense. Ground nuts, chillies, lemon grass, pepper, gingelly, etc., are also being tried for the same reasons. Granted favourable conditions, Para rubber will grow 6 to 10 feet in height per annum for the first three or four years. In girth, the increase is about 4 to 5 inches per annum for the first few years, afterwards increasing more rapidly. Some of the old trees in Ceylon, about thirty years of age, have a circumference of over 100 inches, and are about 80 feet in height. These trees were not grown under the most favourable conditions.

Tapping the rubber tree in Ceylon.—When the tree attains a circumference of

20 inches at a yard from the ground, which is more often than not in its sixth year, tapping is commenced. To speak of the various systems of tapping there is no space available. All are based upon the one main fact, that between the outer bark and the wood there exists an inner bark provided with a system of latex tubes. When one of these tubes is pierced, the latex milk, or sap, exudes. These laticiferous tubes are very minute, and in the Para tree the latex may approximately be said to exude only from the tube incised, or at the most from its near neighbours. It is necessary, therefore, in order to get a good yield of rubber, to pare off each year as much bark in thin shavings as the tree will stand, economy of bark, however, in comparison with the yield, having to be taken into account. Roughly speaking, it may be said that the bark of the tree up to 6 feet from its base is divided up into four parts for four years' tapping. The simplest method is the "half-herring bone." A vertical channel is cut down the tree in order to convey the latex to the cup at the foot of it. Two or more oblique cuts are made a quarter round the tree and connecting with this channel. Every alternate day a thin shaving is taken off the bottom of each of these cuts, and so on until the bark between the cuts is all used up. Then the other side of the vertical channel is begun upon, and when that is finished the operation is repeated on the other side of the tree. The bark grows again fairly rapidly, from above downwards, and from inside outwards. Although the renewal of the bark does not take long, it is some time, however, before the latex tubes are rich in latex, and for this reason, generally speaking, the renewed bark is left untouched for four years, when it has been found to yield as well as the original bark. The greatest care has to be taken not to touch the cambium or wood of the tree, as this not only injures it, but also makes the surface irregular, so that tapping is difficult, or in bad cases impossible. In order to avoid this, many tapping knives have been invented, some of which have met with a fair measure of success.

The preparation of rubber in Ceylon—Coagulation.—The latex, as it exudes from the tree, is in the form of a white milky fluid. Upon standing, however, or by the addition of acid, it coagulates; that is to say, the rubber globules separate out from the rest of the liquid, and, uniting, form a jelly-like substance, sufficiently firm to be handled. *Biscuit rubber.*—At first, this coagulation was done in dairy pans, and the resulting "biscuit" of rubber (so called from its shape) was washed by hand, and put upon wire shelves to dry, a process which took considerable time. *Crêpe rubber.*—Now, however, on most of the larger producing estates, the coagulated rubber is put into a washing machine, consisting of a pair of very heavy corrugated cylinders, revolving at different speeds; an ample supply of water is poured upon the rubber as it goes through the cylinders, which is drawn into the finest films in the process, the operation being continued until the rubber is thoroughly washed, and free from all grit, bark, or other impurities. The rubber coming from the machine in the form of a thin sheet, with numberless corrugations on its surface, is then hung up in the drying-room, and, owing to its thinness and great surface exposed, dries very quickly, and comes on the market in the form of "crêpe." Other forms of cultivated rubber are "sheet," "smoked sheet," and "block."

Cost of rubber cultivation in Ceylon.—Ceylon has long been famous for its labour. Not only has it a native population available for a proportion of the work done on the estates, but it has also the valuable supply of labour from Southern India to drawn upon, and in the past this has formed the main source of supply. With this and the favourable soil and climatic conditions, Ceylon is eminently suited for the growth of rubber. From estimates made by well-known planters in 1905, it would appear that, exclusive of the cost of land, the expenditure required to plant and bring to maturity an acre of rubber amounted to about £20. Since then, however, advances have gone up, contract rates have increased, and planters are spending more on clean weeding than was then thought necessary. It would be safe, however, to put the cost at £25 per acre on a well managed estate of a fair size. This would include everything except the land, the price of which varies,

but will certainly not average more than £5 per acre; or, say, £30 in all, up to the end of the sixth year.

The yield of rubber in Ceylon.—The yield of rubber from individual trees varies enormously. The average per acre for trees of the same age, however, is fairly constant, and, futhermore, the yield per acre is the safest method of calculating possible returns. From the results published in companies' reports, official reports, and the literature on the subject, it is evident that, provided the climatic conditions and soil are suitable, a yield of 100 lb. per acre by the end of the seventh year can be safely reckoned upon, while the eighth year will give 150 lb., and the ninth year 200 lb. per acre, and so on increasing as the trees grow older. Practice has shown, of course, that in most cases a large yield can be got from rubber in its sixth year, and even earlier, so that the figures given can be taken as conservative. The cost of collecting, preparing, and selling this rubber, including all fixed charges, is now known to be about 1s. 8d. per lb., with a great probability of a decrease. The price of plantation rubber in London to-day is about 4s. 2d. per lb. This leaves a margin of 2s. 6d. per lb. net profit. Upon these figures, therefore, it would seem that the initial expenditure of £30 would be covered by rubber obtained in the seventh and eighth years, and that in the ninth year the investment would yield over 80 per cent. These calculations are based on rubber at the present price of 4s. 2d. per lb., but the fluctuations in value during the past few years have been considerable, as shown by the supplement giving the price obtained for rubber from 1861 to 1903. Since 1903, the rubber market has been subject to the same causes as affected nearly every other crude material. The financial crisis in America in the autumn of 1907 resulted in not only a cessation of the American demand, but also in a large quantity of their purchases being thrown upon the market, with the result that rubber fell to 2s. 9d. per lb. Since then, however, it has steadily improved, until to-day (1908) it is worth 4s. per lb.

Guayule rubber.—The very partial success of *Castilloa* plantations in Mexico rendered the appearance of a new plant from which rubber could be extracted by a chemical process highly welcome. Guayule rubber cannot certainly compete with the good sorts of rubber, but it can very well be mixed with them. It is a rubber of medium value. This rubber has been known for a long time, especially in the State of Durango. It was Father Negrete, the Jesuit, who made its value known, eighteen years ago. The Guayule, *Parthagenium argentatum* (*Synantherea mexicana*), is a tree from 8 to 40 inches in height, which flowers in October. Its wood is used as fuel, for which purpose it is very good. It dies after a life of fifteen years. This plant bears several names, such as Guayule, or Hayule (hule means rubber in Indian); in the State of Durango, it is called Yerba de Hule, Yule in the northern parts of San Luis de Potosi, and Jiguihite near Saltello. Moreover, it is sometimes confused with a medicinal plant called Yerba del Negra. There is a mistake also as to the extent of its distribution, which is not very considerable. The districts of Chihuahua, the north parts of Zacatecas and of San Luis de Potosi, the east of Durango, produce the most. It lives more especially at altitudes of 900 to 1700 metres above sea-level in any soil rich in lime. It springs up in sparse tufts or continuous tracts. Its distribution per acre is therefore difficult to ascertain. The plants weigh 100 grammes (say 3½ oz.) to 3 kilos. (6·6 lb.) per stock, with an average of 500 grammes (1·1 lb.). There is on an average 500 to 800 kilos. of plants per hectare (say 440 lb. to 704 lb.) per acre. Altogether one may count on 70 square kilometres (43,400 square miles). Latex does not exist in the bark of the Guayule as in the *Euphorbia* or the *Apocynaceæ.* The rubber is found dissolved in the cellular sap of the wood and the bark. It is not present in the leaves, nor in the fruit; the wood yields less rubber than the bark, but gives a purer product; the ratio of the two quantities is as 7 to 2. The bark also contains aromatic balsamic bodies, and sometimes a noxious gummy product, which flows in drops over the surface of the shrub. This product diminishes the value of the Guayule. The plants are allowed to dry in the air for some days, so as to be able to crush them. They produce generally 44·5 per cent. of bark, 47 per cent. of

wood, and 8 per cent. of leaves. Fifteen pesos (say 31s. 3d.) are paid for a ton of Guayule. But the price varies with the situation of the country or the factories. Guayule is transported in trusses by rail.

Extraction processes.—There are several of these. Bergner, Mexican Patent 2147, crushes the plant in a Krupp disintegrator, then in a mill with balls until all

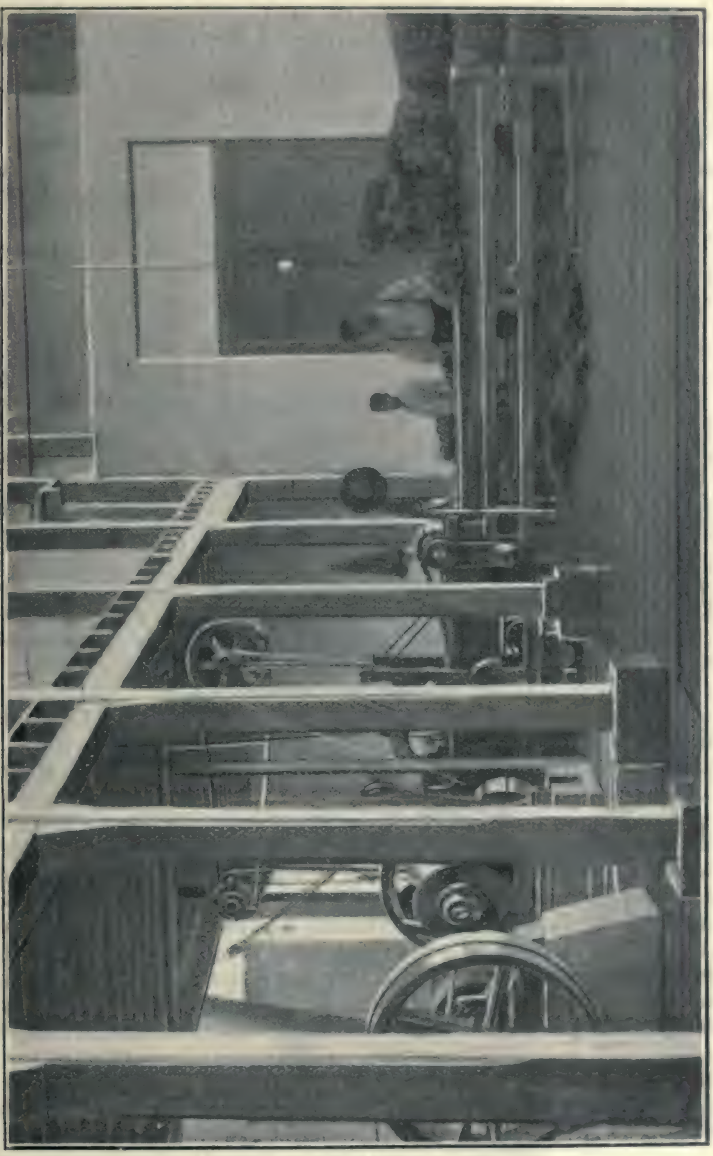


FIG. 33.—Machinery for crushing the Guayule plant in a Mexican Guayule rubber factory, preparatory to extraction of rubber therefrom.

the wood is separated, and the rubber forms balls with the remaining wood. These balls are placed in a steam jacketted iron vessel. During boiling some soda is added, but that is not absolutely necessary. The whole is then run into wooden vessels, where the rubber is washed with cold water. It is afterwards sifted in a sieve with a false bottom. The rubber is again washed with soda and precipitated by chloride of calcium, possibly injurious owing to the action of the free chlorine on

the rubber. The methods by which the finely ground wood is treated by steam are more simple. Soda ley, of 10° to 12° B., is used with a pressure of 6 to 14 atmospheres (?). The soda is neutralised by weak acids. Possibly, the American factories use carbon disulphide for this extraction. The rubber obtained by the ordinary method is black on the surface, and grey in the interior. Its drawback is that it contains 27 per cent. of gummy or aromatic substances, which render it tacky. Guayule is easily vulcanised; its unpleasant smell comes from the aromatic bodies which it contains. At Jimulco, this rubber has been so much improved that there are only 10 to 15 per cent. of substances present other than its water. This variety sells at 5s. the kilo. (2s. 3d. the lb.) instead of 3s. per kilo. (1s. 4d. the lb.), the price of the former. Rubber which only loses 5 per cent. on washing is worth 7s. to 8s. the kilo. (3s. 2d. to 3s. 7d. per lb.) in Great Britain or Germany. The plant produces according to its humidity 8 to 12 per cent. of crude rubber, say 6·8 to 10 per cent. of good caoutchouc. A factory to produce a ton a day of Guayule rubber would require to treat 10 to 14·86 metric tons of plants, which would require 16·7 to 23·8 hectares (40 to 60 acres) to exploit per day, say 6·012 to 8·588 hectares annually (say 15,000 to 21,473 acres). The difficulties of such an undertaking are evident, especially when the factory is far from the spot of production. Asses are the animals best adapted for the transport of the raw material. The ton of Guayule shrubs transported by them costs 4·97 to 5·80 pesos (say 10s. 6d. to 12s.) for a journey of 20 kilometres (12·4 miles). The want of water for the recovery of the rubber is a cause of much anxiety. The selling price of Guayule is low. It may be taken that the 75,000 square kilometres producing Guayule will only yield 26,250 to 37,500 tons of rubber. It is therefore desirable to cultivate these plants, and cheap land lends itself to this admirably. It is not known how long the seed of Guayule takes to develop. In eight to ten years the plants reach their average height, but young plants also yield rubber. One can reckon on 200 grammes per plant as weight after six years, and 4000 kilos. (say 4 metric tons) of plants per hectare (say 1·6 tons per acre). Whether the rubber from cultivated plants will be the same as that from the wild Guayule remain to be seen. Guayule has the following good points:—1. It is not exacting as regards soil or humidity. 2. It grows in a more healthy climate than the Tropics. 3. It may be cultivated all the year round. 4. Its culture gives reason to hope for profits. As some parts of South Africa have an analogous climate, it is desirable not to lose sight of this plant.

Funtumia elastica (*Kickxia africana*, formerly so called).—A new rubber plant came all at once into prominence in the colony of Lagos in 1894, namely, a handsome tree, locally known as Ire, Ireh, or Ereh, belonging to the same natural order as the *Landolphias*. It was erroneously determined from data accumulated at Kew to be *Kickxia africana*, Benth., a tree said to be widely distributed in West Africa from Sierra Leone to the delta of the Niger, the island of Fernando Po, and the Gaboon. It is believed, says Morris, that rubber was first obtained from it on the Gold Coast in 1883. In 1888 seeds of it were introduced to Europe as a substitute for *Strophanthus* seed, and stated to be worth 72s. per lb. They were called "indiarubber" seeds, but nothing further could be obtained respecting them. The following extracts are taken from the "Kew Bulletin," 1890 (pp. 242, 247):—

"In September 1894, Kew received from Captain Denton, C.M.G., two pieces of the trunk of the Lagos rubber tree, each about 10 inches to 1 foot in diameter, scored with the marks of the rubber gatherers. They were sent as the 'female' rubbertree, a name, we learn, that is locally applied to the *Kickxia africana*, Benth. It is thus distinguished from *Holarrhena africana*, quite a different plant, which is fancifully called the 'male' rubber tree. The latter is also an Apocynaceous plant, but not known to yield any rubber.

"In tapping the trees the bark is first cut in a vertical direction from the bottom to the top. This single line is about ½ to ⅝ of an inch broad, and deep enough to reach the inner bark. This forms the main groove; on each side of this two series of oblique grooves about 2 feet apart are cut, each running into the

main groove. The side grooves are made, beginning at the top, and gradually reaching the base of the tree. All the milk exuding from the lateral grooves will find its way into the main groove, and so ultimately reach the bottom, where a vessel is placed to receive it. [This is the herring-bone system of tapping.] When sufficient milk has accumulated, it is then collected and made into rubber.

"The methods adopted for coagulating the milk are then described. These are at present of two kinds, namely, 'the cold process' and 'the heat process.' The cold process is chiefly practised by the Fanti men introduced from the Gold Coast. A cavity is excavated in the trunk of a fallen tree so as to form a cistern of the capacity necessary for holding the milk collected during several days. Into this the rubber gatherers pour the milk, after straining it, from day to day until it is quite full. It is then covered with palm leaves and left for twelve to fourteen days, and sometimes much longer, depending on the season, until most of the watery portions have either evaporated or sunk into the wood. After being kneaded and pressed together, the rubber thus obtained has a dark brownish colour, with the inner portions of a slightly lighter colour. Such rubber is known locally as 'silk rubber.' The local price is from 10d. to 1s. 2d. per lb. The heat process is the one generally adopted by the natives of Lagos. This is much simpler in working, as it disposes of all the milk collected at the close of each day. After being strained the milk is placed in a vessel and boiled. The rubber begins to coagulate almost directly the heat is applied, and after the boiling is over is removed in a somewhat sticky condition owing to being burnt, and of a blackish colour. The local price of this rubber is from 9d. to 1s. per lb. It is pointed out that the heat process, though simpler, impairs the quality of the rubber, and is calculated to injure the industry. It is probable that if the heat process were somewhat modified the results would not be so injurious. An experiment was tried at the Botanic station to coagulate the milk by heat but not applied directly to it. The result was much more satisfactory. The rubber came off a milky white colour, and after being pressed it was clean and firm without being sticky. The history of this new rubber industry in Lagos is full of interest, and illustrates the wonderfully rich resources of the vast forests of West Africa. It shows also very clearly how largely these resources can be developed by judicious and intelligent action on the part of the government.

"Should the new rubber *Kickxia* continue of commercial value, there is no doubt that it will eventually be possible to establish regular plantations, and thus make the industry a permanent one. It has always been seen that, owing to the climbing habit of the species of the *Landolphia*, which have hitherto yielded African rubber, it was not practicable to cultivate them in regular plantations, as they required the support of other plants, and when once tapped, many years would have to elapse before they would be fit to yield another crop. With the *Kicksia* these practical difficulties disappear. According to Chalot, *Kickxia africana* has been found lately in Gaboon. Specimens have been measured 1 metre in circumference and 12 to 15 metres high. Each tree is estimated to yield annually without any injury."

But the Kew authorities were apparently in error in their botanical determination of this rubber tree, for Wright, *Cantor Lectures*, 1907, says:—

"*Funtumia*. This genus has lately become known as a source of rubber in Africa. It is still much confused with the genus *Kickxia*, and it is as well to again point out that Africa does not possess a single species of *Kickxia* of value as a rubber-producing plant. The four species of *Kickxia* acknowledged by Stapf. are found only in Java, Celebes, Philippine Islands, and Borneo. The genus *Funtumia* is partly African, and is represented by three species—*F. elastica*, Stapf., *F. africana*, Stapf., and *F. latifolia*, Stapf. The species of importance as a source of rubber in Africa is *F. elastica*, Stapf. Its occurrence has been recorded in Liberia, Gold Coast, Ashanti, Lower Nigeria, Cameroons, Mundame, French Congo, Congo Free State, Uganda, etc. The rubber from this species is very valuable, possessing when properly prepared from 80 to 90 per cent. of caoutchouc. *Funtumia elastica* has been described as a tree with a cylindrical trunk which attains a height of 100 feet; sometimes the

tree occurs more abundantly in local areas, and out of an area of about 54 square miles as many as 1,760,000 trees have, as previously stated, been estimated to occur.

Rubber in Cochin (*India*).—Rubber was first planted on any scale in 1905, when Mr. K. E. Nicoll obtained a grant of forest land at Palapilly, behind the Government teak plantation. This was a well-situated block, at the foot of the hills, with the Chemoni River running through the centre. Some 40 acres were opened in 1905; and later on, in the same year, Mr. E. G. Windle, on behalf of a syndicate, took up an adjoining block of forest now called Pudukad. In 1906 there were some 300 acres opened on each place, and in 1907 the balance of the land was opened, Pudukad being in all some 650 acres, and Palapilly nearly 500,

FIG. 34.—Two and three-quarter years old Para trees, Palapilly estate, Cochin.

the two places making a fine sheet of over 1100 acres of rubber. The conditions here are very favourable, the elevation being almost sea-level, rainfall about 150 inches, and surrounding hills sheltering the basin from wind. As a result, growth has been remarkably fine, and, according to those who have seen both, it may challenge comparison with fine Straits growth. The plantations are some eight miles by cart road from the Pudukad Station on the Cochin Railway, and about twenty miles from the coast. In 1906 also a grant of Government forest, six miles from Trichur Railway Station, and lying on the main road from Trichur to Palghat, was obtained by E. G. Windle and R. E. Campbell-Gompertz, who opened 400 acres, and subsequently disposed of the block to the Cochin Rubber Co. Ltd.,

of Colombo, in whose name the Government title was issued. This consists of 1000 acres in all, of which 400 acres were opened in 1906, 200 in 1907, and 200 in 1908, 200 being forest. Elevation and rainfall are much the same as at Pudukad and Palapilly, and growth has been excellent. There are, therefore, at present some 1900 acres of Para opened in Cochin. Many other applications for land have been made, but were refused by the Durbur (Cochin Government), on the ground that it had to be seen whether rubber would be successful. There seems no room to doubt this now, and it is to be hoped that further land may be available to the public for tea as well as rubber. The forest slopes, which are now being tapped by the tramway, might reasonably be surveyed with the view of opening suitable parts; there are probably 50 to 100,000 acres which would grow one or other of the above products without unduly interfering with forest resources.

Rubber cultivation in Dutch Borneo.—Borneo with 13,000 square miles is larger than Britain, Germany, and Switzerland combined. The interior is more healthy than districts somewhat nearer the coast. Starting from the port of Bandjermasin (3° 22′ latitude and 114° 38′ longitude), going into Negara and Tabalong, Tandjong is reached at 230 kilometres from Bandjermasin, where there is virgin soil and rubber trees which yield Borneo rubber, namely, *Ficus consociato*, and the vines *Willughbeia* and *Urceola*. There is not a single *Hevea* nor *Ficus elastica* which yield wild rubber. The rubber goes to Bandjermasin, the chief port of the south and west of Borneo.

This rubber was formerly adulterated by means of all sorts of detritus, which brought it into discredit. The climate is hot. But the heat is not often unbearable; 2½ metres of rain fall annually. The European can therefore live there. Schram of Dresden lived there eight years, and saw no European die there. There is no want of cheap labour if their habits be not crossed at every step. Everything goes well since private companies have set to work in the country. Trade communication is by rivers. Telegraphs and telephone have been in use some years, and life there is not one of isolation. Plantation experiments have been made in the district of Tabalong and Kaloewa with gutta and rubber trees, *Palaquium oblongifolium et borneense*, *Hevea braziliensis*, *Ficus elastica*, *Castilloa elastica*. The *Ficus elastica* appears to succeed best. Plantations are also to be found in Martapoere, Kendagan, and Doesoen; marshy ground is less propitious. The *Ficus* neither fears humidity nor drought; its wood burns badly, an advantage against fire. In 1892, "layers" of *Ficus elastica* from the Botanic Garden of Java were planted in the district of Tabalong by a German tobacco company. There are now more than 100,000 trees. The propagation of this tree is simple and costs little. Its product analysed in Holland and Germany was regarded as very good, and it was quoted at 6·8 marks per kilo. in Hamburg in 1903. Its culture is therefore assured of success. Weber and Schær of Hamburg rate this rubber as follows:—No. 1, *Cakes.*—Pale, porous, moist inside, pure, resilient, might be used for making ebonite; value about 6 marks to 6·3 marks per kilo. No. 2, *Twits.*—Very dry, resembles African twits; value 8 marks per kilo. No. 3, *Scraps*—Resembles Java rubber, fresh and white, resilient; value 6·7 marks per kilo.

The Kolonial Museum of Haarlem gives the following analysis:—

TABLE XVI.—SHOWING THE COMPOSITION OF *FICUS ELASTICA* RUBBER CULTIVATED IN BORNEO (HAARLEM KOLONIAL MUSEUM).

	I.	II.
Pure Rubber	89·5	85·6
Resins	3·7	6·4
Impurities	0·2	1·0
Water	6·6	7·0
	100·0	100·0

Dieterich Helgenberg also analysed Borneo *Ficus* rubber, and found :—

TABLE XVIA.—SHOWING THE COMPOSITION OF *FICUS ELASTICA* RUBBER CULTIVATED IN BORNEO (HELGENBERG).

	Per cent.
Moisture	1·025
Resin	4·2
Ash	6·514
Non-rubber	5·51
Pure Rubber	88·56 to 88·72

It is a good rubber, compared with certain Asiatic rubbers, which have less than 30 per cent. of rubber. Van Romburgh and Henriques recommend the plantation of the *Ficus* in Borneo. The oldest trees in a plantation of 5000 trees in Java Pamanocken in Trassemlanden, planted since 1863, yield, according to Dinet, 1000 grammes of rubber per tree in 1899, 1640 in 1900, and 1310 in 1901. Van Romburgh also gives some data on this subject. At Tijandi in Bantero, trees of twenty-four years old yield 2½ kilos. to 3 kilos. per tree. Trees of two to six years yield 530 grammes of rubber. According to Van Romburgh, only plants in full vigour should be planted. They may be tapped every year after eight years. Collet estimates that a five-years-old tree gives 500 grammes of rubber.

Rubber in the Philippines.—The U.S.A. are making strenuous efforts to develop the exploitation of indigenous species (all of which are vines); moreover, a recent official report says a species of Para tree is now growing in Manilla, and apparently the climate is suitable. The Bureau of Agriculture has distributed many Ceara rubber seeds, and the growth of the seedlings is marvellous.

Much more might be written, did space permit, of the cultivation of rubber-bearing trees in tropical lands all round the globe—in the West Indian Islands, Dominica, St. Lucia, Jamaica, Trinidad; in Africa, on both the east and west coasts; and in Madagascar, Travancore, Java, Malaya, and other parts of Asia and the adjoining archipelago. The vast demand for this product has led to innumerable experiments, which will probably result in a continuous "rubber belt" encircling the globe at that part of its circumference which favours the growth of rubber-producing plants.

Gold Coast rubber.—First exports in 1880, 1200 lb.; in 1890 they exceeded 3¼ million lb. From 1891 to 1900 rubber most important export value in 1899, £555,731; decade average, £321,265. But 1901–03 showed marked decrease due to Ashanti disturbances and destruction of forest trees by unskilful tapping, and to French and German Colonial rubber no longer being shipped from here, and enticements to labour in mines, cocoa culture, etc. Hence the value fell in 1901 to £88,602 (lower than any year since 1899). But rubber—value £360,644—in 1904 resumed first place in exports, and if figures for 1905–07 are slightly less, and values for output of gold and cocoa exceed respectively £1,000,000 and £500,000, the rubber shipped in any one of these years is greater than the average for the decade when it was the staple product of the colony.

Numerous trees planted at government Botanic Stations at Aburi, Kumasi, Tarkwa, and near Cape Coast Castle, form nursery centres, and seeds and seedlings of Para and various indigenous rubber-producing plants are distributed therefrom. Travelling instructors, European and native, educate natives to more scientific methods of tapping and preparing rubber for market. Simple literature bearing on subject in English and the vernacular has been circulated. A Commission of Inquiry recently inquired into details of industry, so as to maintain and improve sources of supply, prevent adulteration, and obtain best prices.

The two principal sources of Gold Coast rubber are (1) *Funtumia elastica* (West African rubber tree), and (2) *Landolphic owariensis*, both indigenous to Colony. (3) The tree *Ficus Vogelii*, which furnishes a rather inferior rubber, also occurs in Gold Coast, but is not now exploited by natives to any extent. Recently, Para cultivation has been successful in Colony, and may prove important as future source of Gold Coast rubber.

Gold Coast lump rubbers mostly produced by *Funtumia elastica*, but from defective native collection and preparation are usually inferior. Natives invariably add non-caoutchouciferous latices to *F. elastica* latex before coagulation; resultant rubber very resinous. Preparation of large lumps deteriorates rubber, as it retains mother-liquor and albumen, usually fermenting in transit; it also heats, becomes sticky, and smells badly. Hence Gold Coast rubbers realise low prices. When fine hard Para is 4s. per lb., Gold Coast lumps is 1s. 7d.; "Softs," 1s. 3d.; "Paste," 5½d.; "Niggers," 1s. 8d. But *F. elastica* yields excellent rubber if properly prepared. Natives are induced to prepare biscuit rubber, and to cease adding other latices. Recently, many specially prepared samples of *Funtumia* rubber were sent to Imperial Institute for valuation, to show advantages from rationally prepared rubber.

TABLE XVII.—ANALYSES OF GOLD COAST RUBBER.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Moisture	..	..	3·6	4·7	3·1	3·7	0·6	0·6	..	1·0	..	0·4	0·8	0·39	0·57
Caoutchouc	84·6	86·9	70·0	72·7	80·2	79·2	88·0	89·0	88·6	91·3	90·6	51·6	60·6	95·53	95·96
Resin	5·8	9·1	9·5	9·2	8·0	7·2	8·6	8·1	8·9	4·7	6·2	44·0	35·6	3·90	3·25
Proteids	8·3	3·4	10·2	10·2	7·8	9·6	2·3	1·9	2·1	0·9	0·9	3·5	1·7	..	..
Insoluble matter	..	..	6·7	3·2	0·9	0·3	..	..	..	2·1	2·3	0·5	1·3	..	..
Ash	1·3	0·6	..	..	..	..	0·5	0·4	0·4	..	..	..	..	0·18	0·2

A. By letting *Funtumia* latex coagulate by air exposure, London value, 5s. 3d. per lb.—*B*. Same latex coagulated by boiling, London value, 4s. 6d.; Para at 5s. 4d.—*C*, *D*, *E*, *F*. Same latex spontaneously coagulated after adding a little formalin, London value, 4s. 9d.; Para at 5s. 2d.—*G*, *H*, *I*. Same latex coagulated by hot infusion of *Bauhinia reticulata*, London value of *G* and *H*, 4s. to 4s. 3d.; Para at 4s. 7d. Of *I*, 2s. 8d. to 2s. 10d.; Para at 3s. 5½d.—*J*. Crepi Ball from *Landolphia owariensis*, London value, 4s. 3d. to 4s. 6d.; Para at 5s. 4d.—*K*. Pempeni rubber from *L. owariensis*, London value, 3s. to 3s. 3d.; Para at 3s. 5½d.—*L*, *M*. *Ficus Vogeli* (Inferior). Trials as to technical uses value, being conducted for Imperial Institution.—*N*, *O*. *Hevea Braziliensis*, London value, 4s. 6d. to 4s. 7d. The analysis compares favourably with Ceylon and Malay States Para biscuits, and show that the Para tree will furnish excellent rubber in the Gold Coast.

APPENDIX TO CHAPTER III

PARA RUBBER CULTIVATION

Official Estimate for 1000 Acre Estate; 250 Acres to be Opened Each Year.

Expenditure.

1st Year.	$
Premium	3,000
Survey fees	1,000
Rent	1,000
Clearing, felling, and burning 250 acres ($15 per acre)	3,750
Lining, holing, and planting 250 acres ($6 per acre)	1,500
Plants	800
Roads and drains ($6 per acre)	1,500
Bungalow	2,000
Lines	1,500
Medical—Hospital, medicines, etc.	2,000
Labour;—Advances, immigration fees, etc.	1,500
Superintendence	3,600
Tools and sundries	1,000
Total	24,150

2nd Year.	
Rent	1,000
Clearing, felling, and burning 250 acres	3,750
Lining, holing, and planting 250 acres	1,500
Plants	800
Roads and drains	1,500
Medical	1,000
Labour	1,000
Superintendence	4,000
Tools and sundries	750
Weeding 250 acres	2,500
Supplying	100
Total	17,900

3rd Year.	
Rent	1,000
Clearing, felling, and burning 250 acres	3,750
Lining, holing, and planting 250 acres	1,500
Plants	800
Lines	1,500
Roads and drains	1,500
Medical	1,000
Labour	1,000
Superintendence	4,000
Tools and sundries	1,000
Weeding 500 acres	6,000
Supplying	100
Total	23,150

4th Year.	$
Rent	1,000
Clearing, felling, and burning 250 acres	3,507
Lining, holing, and planting 250 acres	1,500
Plants	800
Roads and drains	1,500
Medical	1,000
Labour	1,000
Superintendence	4,000
Tools and sundries	1,000
Weeding 750 acres	12,000
Supplying	100
Total	27,407

5th Year.	
Rent	1,000
Roads and drains	800
Medical	1,000
Labour	1,000
Superintendence	4,000
Tools and sundries	1,000
Weeding 1000 acres	15,000
Total	23,800

6th Year.	
Rent	1,000
Roads and drains	800
Labour	1,000
Medical	1,000
Superintendence	4,000
Tools and sundries	1,000
Weeding 1000 acres	17,000
Total	25,800

7th Year.	
Rent	4,000
Roads and drains	800
Medical	1,000
Labour	1,000
Superintendence	4,000
Tools and sundries	1,000
Weeding 1000 acres	17,000
Total	28,800
8th and following years as 7th year	28,800

With the exception that the cost of weeding gradually decreases till, in the 11th or 12th year, it is practically *nil*.

Profits.

7th Year.	$
250 acres, planted 150 trees per acre, at 1 lb. rubber per tree, sold at 3s. per lb.	48,214
250 acres, planted 150 trees per acre, at $1\frac{1}{2}$ lb. rubber per tree .	72,321
Total .	120,535
Less cost of production, shipping, etc., of 93,750 lb. at 1s. 6d. per lb.	60,268
Net profit .	60,267

8th Year.	$
250 acres at 1 lb. per tree and 3s. per lb.	48,214
250 acres at $1\frac{1}{2}$ lb. per tree and 3s. per lb.	72,321
250 acres at 2 lb. per tree and 3s. per lb.	96,428
Total .	216,963
Less cost of production, etc., 253,125 lb. at 1s. 6d. per lb. .	108,482
Net profit .	108,481

9th Year.	$
250 acres at 1 lb. per tree and 3s. per lb.	48,214
250 acres at $1\frac{1}{2}$ lb. per tree and 3s. per lb.	72,321
500 acres at 2 lb. per tree and 3s. per lb.	192,856
Total .	313,391
Cost of production, etc., 243,750 lb. at 1s. 6d. per lb. . . .	156,696
Net profit .	156,695

10th Year.	$
250 acres at $1\frac{1}{2}$ lb. per tree and 3s. per lb.	72,321
750 acres at 2 lb. per tree and 3s. per lb.	289,280
Total .	361,601
Less cost of production, etc., 262,500 lb. at 1s. 6d. per lb. .	180,800
Net profit .	180,801

11th Year.	$
1,000 acres at 2 lb. per tree and 3s. per lb.	385,710
Cost of production, etc., of 300,000 lb. at 1s. 6d. per lb. . . .	192,857
Net profit .	192,853

And so on each year, annual profit $192,853, with a probability of still increased yield.

Abstract of Profit and Loss.

	Expenditure.	Profit on rubber.	Net profit on estate.		Expenditure.	Profit on rubber.	Net profit on estate.
	$	$	$		$	$	$
1st year	24,150	...	...	7th year	28,800	60,267	31,467
2nd ,,	17,900	...	...	8th ,,	28,800	108,481	79,681
3rd ,,	23,150	...	...	9th ,,	28,800	156,695	127,895
4th ,,	27,650	...	...	10th ,,	28,800	180,801	152,000
5th ,,	23,800	...	...	11th ,,	28,800	192,853	164,053
6th ,,	25,800	...	...	12th ,,	28,800	192,853	164,053

Expenditure with interest at 5 per cent. up to end of 6th year, $168,670 (£20,000).

Net Profit on Estate after Deducting 5 per cent. Interest on Capital.

Net profit.	$	Net profit.	$
7th year . .	22,967 or 13 per cent.	10th year . .	143,500 or 84 per cent.
8th ,, . .	71,181 ,, 42 ,,	11th ,, . .	156,553 ,, 92 ,,
9th ,, . .	119,395 ,, 70 ,,		

And so in future years with a probability of increased yields.

Abstract of Profit and Expenditure.

	$	£	s.	d.
Capital expended	168,670	(19,678	3	4)
Profit	22,967	(2,679	9	8)
	71,181	(8,304	9	0)
	119,395	(13,929	8	4)
	143,500	(16,741	13	4)
	156,355	(18,241	8	4)

CHAPTER IV

CLASSIFICATION OF THE COMMERCIAL SPECIES OF RAW RUBBER

Chief classes.—The different species of raw rubber which come on the international market may be divided, according to their geographical origin, into four chief classes :—

1. *American rubbers subdivided into* { South American rubbers. / Central American rubbers.
2. *African rubbers subdivided into* { West African rubbers. / East African rubbers.
3. *Asiatic rubbers.*
4. *Oceanic rubbers.*

Origin of different designations.—The trade has not always given to each of these different varieties a uniform designation. One sort is sometimes known by the name of the *province* which more especially produces it, although the same variety is likewise met with in other countries, and to an equal extent; sometimes by the *port of shipment*, or of the *central market town* of the substance. Even the *shape* is often put under requisition to design a special brand.

Certain brands disappear to reappear in a new and better form under a new name.—Commercial denominations are very variable, and some sort well known to merchants of twenty years ago has disappeared, to give place to another, although the product comes from the same plants and the same countries; the mode of preparation has alone changed and necessitated this alteration. A rubber, of reputed inferior quality, reappears under a new brand, which raises the price. But the label is not all. In changing the name the rubber has been modified, and, above all, improved.

The study of each commercial sort impracticable.—We shall not examine each commercial sort individually; they are subject to such variations that the data of to-day might not be correct to-morrow. Incessant progress in preparing the raw material, exhaustion of one rubber tree and its replacement by another, render such work uncertain and of doubtful value.

Description of the Synoptical Tables.—The list of the different commercial varieties at present on the market has been condensed into a synthetical Table, and opposite each variety the geographical origin of the species, its botanical origin, the method of coagulation adopted, which is indicated by the abbreviated notation adopted in the chapter preceding the Table of the different methods of coagulation. The usual port of shipment, when known, is also given, the country or the market which more particularly imports it, the tangible form under which the substance comes to market, its outside surface appearance, the texture of its section, the peculiar smell often given off by each kind, the frequent adulterations to which they are subject, the waste in their industrial working, the estimation of its commercial value. Finally, in the remarks column there is mentioned, if need be, any important peculiarity for which a place could not be found in the other columns.

No pretence is made of having thereby accomplished a work of rigorous precision and exact valuations. Such results are only possible with products manu-

factured in a regular, methodical, and almost mathematical manner. In the present instance we have to deal with a substance which is the product of the isolated efforts of individual workers, one of whom is more indolent, the other more active; one more honest, the other more cunning and less scrupulous; the one follows the old routine, the other more of an innovator, and more especially an observer. The result of all this is an infinite variety in the production of each sort, which renders this classification extremely difficult. However imperfect it may appear to be, it enables one to encompass with a single glance of the eye the generality of the indiarubber products, with the essential characters of each variety, and to give an exact enough idea of the present production.

[TABLE.

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

I. American Rubbers—

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
PARA. (1st fin. Sininga fina, the native *Borracha*, up-river hard cure; and Para Fine Islands, soft cure).	Amazonia (Brazil). Similar rubber is obtained from Peru, Bolivia, and Venezuela.	*Hevea* (various species): *H. Braziliensis*, *lutea*, *benthamrana*, *panaflora*. *Micrandra*.	1 α I. pp. 40 *et seq.*	Para (Belem), Manaos.	Liverpool, London, Havre.	Cases of 130 to 140 kilos. (286 to 308 lb.).	Formerly came to market in the shape of little figures, bottles, pears, shoes. Now as cakes and biscuits. The Lower Amazon cakes smaller, 3 to 5 kilos. (6⅗ to 11 lb.). The Upper Amazon cakes larger, 10 to 15 kilos. (22 to 33 lb.).
PARA (½ fin. Entrefin Grossa).	*id.*	*id.*	Mixture of 1 α I. and 1 β III. pp. 45 *et seq.*	*id.*	*id.*	*id.*	*id.*
PARA SERNAMBY (Negroheads), *Cabeca de Negro.*	*id.*	*id.*	*id.*	*id.*	*id.*	Cases or barrels of 200 kilos. (say 4 cwt.).	Sometimes in the shape of rather big blocks, but more often in irregular shaped lumps of about the size of the fist, and agglutinated by tight packing.
VIRGIN SHEETS (White Para).	Province of Matto Grosso (Brazil).	*Hevea.*	3 ε. pp. 49 *et seq.*	Manaos. That from north shipped from Para.	..	..	Cakes in the shape of parallelopipedons of various dimensions. Large-sized cakes with sharp regular edges are generally 0·60 metre in length by 0·30 metre in width by 0·15 metre in thickness (24 × 12 × 6 in.). The small cakes are about half this size.
MOLLENDO.	Bolivia.	*id.*	..	Mollendo.	..	..	..
CEARA SCRAPS.	Province of Ceara (Brazil).	*Manihot Glaziowii* (*Manisoba or Leitera*).	1 β III. pp. 46 and 54 *et seq.*	Ceara.	*id.*	..	The milk coagulates as tears on the trees. Small strips or networks of tears agglomerated into balls, sometimes of considerable size, and which, when packed fresh, eventually amalgamate together to form blocks weighing as much as 150 kilos. (say 3 cwt.).

OF COMMERCIAL CRUDE INDIARUBBER.

(1.) SOUTH AMERICA.

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
Dark brown, inclining to black.	The colour of the section in the direction of the thickness, from the outside to a depth of 1 centimetre, say 3/8 of an inch, is changed by insensible gradations to a slightly amber-tinted white, the general tone of the rest of the section perpendicular to the first. Apparent foliæ or pellicles tell the origin of this rubber. New cakes subdivide under the thumb into as many pellicles as there have been superimposed layers.	Slightly smoky, from the method of preparing the rubber.	Little or no extraneous matter. Humidity variable, according to date of collection. Sometimes adulterated by an admixture of the latex of *Mimusops elata*, *Marcandaruba*.	10 to 15 %. [12 to 18, Weber.]	Sensitive and elastic *par excellence*. Resin in dry washed rubber, 1·3 %; ash, 0·5 %.	The cakes of Para rubber often bear the hollowed-out initials of the producing factories (called the brand, as in the case of indigo). Collected during the dry season—end of June to middle of October. During the rainy season the latex is too poor in rubber. Moreover, the collectors could not work on account of bad weather. *Borracha* arrives abundantly on the Brazilian markets from the end of July to the end of December. Parafin is the standard against which quality all rubbers are valued.
id.	Exhibits quite different characteristics from *Para fin*. The method of coagulation explains this difference. The portions evaporated without being smoked are of a dirty white, whilst those that have been smoked are amber brown.[1] (See Observations.)	Odour less pronounced than in the preceding variety. Smell of methylamine.	Few foreign bodies. More moisture than the above.	15 to 20 %.	Less sensitive. Resin, 2·5 %; ash, 0·6 %.	[1] Dirty milky-white is always a sign of moisture, due either to the latex itself or the serum being imprisoned in the rubber. Horny transparency is, on the contrary, a sign of good quality. This variety is only met with on the market in small quantity.
Blacker and rougher than fine Para.	Yellowish white, marbled with black striæ. Cuts like fine cheese.	*id.* Sometimes smells mouldy.	Often mixed with sand. Moisture considerable. Mixture of "dead" rubber without nerve or elasticity.	20 to 40 %.	Is awanting in sensitiveness.	Negrohead is made up of rounded masses of uncured rubber, with sometimes flattened discs, the result of coagulation in the clay cups.
Bright brown.	Straw yellow with greenish marbling, especially on the edges.	..	..	15 to 30 %.	Less sensitive than brown Para, yet good and strong.	Collected from August to February. Like Para, is divided into fine, ½ fine, and Sernamby. Another sort of Matto Grosso rubber from the southern part of the State is probably got from *Hancornia speciosa*.
..	..	..	..	..	Nearly equal to Para.	..
More or less deep amber.	Bright amber, almost translucid; when drawn out, becomes white and opaque.	*Sui generis* very pronounced; becomes nauseous in moist heat.	Always mixed with vegetable débris, and often with sand, as much as 15 % of moisture.	20 to 25 %. Lower qualities charged with earth as high as 50 %.	Rather sensitive and esteemed. A dry rubber, very elastic and free from stickiness. Resin, 2·4 %; ash, 2·8 %.	The serum from the coagulation of the Ceara rubber is to a greater or less extent eliminated by mechanical pressure. The *Manihot* is the indiarubber tree of arid dry ground.

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

1. American Rubbers—

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
Pernambuco (Mangabeira).	Province of Pernambuco (Brazil), Bahia, Southern Matto Grosso, Uruguay.	*Hancornia.*	3 ε. pp. 49 *et seq.*	Rio Janeiro, Bahia; that from Matto Grosso by River Parana through Paraguay.	Liverpool.	..	As biscuits. Sometimes in the form of rectangular slabs of different sizes, sometimes 1·50 metre in length, 0·6 to 0·7 metre in width, and 0·08 to 0·1 metre in thickness (say 60 x 24 to 27 x 3 to 4 in.).
Maranham.	Province of Maranham (Brazil).	..	3 ε. pp. 49 *et seq.*	..	..	..	..
Bahia.	Province of Bahia (Brazil).	*Hancornia.*	1 β I. pp. 47 and 53.	..	United States.	..	Irregular masses or bulky sheets, which sometimes weigh as much as 15 to 20 kilos. (33 to 44 lb.).
Carthagena (Essequibo).	Colombia.	*Heveas.*	1 β III. pp. 45 *et seq.* 46 *et seq.*	Carthagena, Savanilla.	United States, France.	..	Bulky masses which may weigh as much as 80 kilos. (176 lb.), proceeding from sheets of variable dimensions placed in juxtaposition, or attenuated tangles re-folded on themselves like Nicaragua Scraps.
Ciudad Bolivar (Colombia-Virgin).	Venezuela.	*Heveas, Callotropis procera, Hancornia speciosa, Sapium (biglandulosum)* (Lechere).	1 α I. pp. 40 *et seq.* Sometimes pp. 49 *et seq.* 3 ε. (Lucien Morisse). pp. 51 *et seq.*	Bolivar. Sometimes Manaos.	Hamburg, United States.	..	Same as Para.
Cayenne.	French Guiana.	*Heveas.*	1 α I. pp. 40 *et seq.*	Cayenne.	France.	..	*id.*
Peru and Peru Sernambillo.	Peru.	*Hevea, Cameraria la folia, Hancornia speciosa.*	1 β I. 3 ι. 3 ε. and punctures to evacuate the serum. pp. 45, 49, and 51 *et seq.*	Iquitos.	..	..	Bulky blocks, or like Para. Sernambillo, like Sernamby Para.

OF COMMERCIAL CRUDE INDIARUBBER.

(1.) South America—*continued.*

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation	Observations.
Orange red, with saline efflorescences.	White rose. There are numerous pockets shown in the section, filled with serum containing alum, which has been used as the chemical coagulating agent.	..	Often also coagulated with salt in excess.	40 to 60 %. [30 to 40, Weber.]	Little elasticity, flabby. In certain cases only used on account of its fine colour. A wet rubber. Possibly affected by method of coagulation. Resin, 5·9 %; ash, 3·1 %.	States of Minas-Geraes and Guyaz have largest production, whence one half is shipped to Rio de Janeiro and the other half to Bahia. Export duty, 14 per cent. Becomes brittle, hard, and friable with age. This defect is attributed to the presence of alum. This quality has a tendency to disappear, and be replaced by Maranham.
Smoother skin, more brilliant, no efflorescence.	White rose which, in the air, assumes a deep wine-lee tint. Few or no pockets.	..	..	25 to 30 %. 30 to 35 %.	More sensitive and elastic. And thus so far superior to previous brand. Resin, 5·8 %; ash, 2·4 %.	The presence of sugar has been determined in mother liquor collected from this rubber.
Orange red coat.	White rose. Pockets filled with serum, and very often with non-coagulated latex.	..	Wood, vegetable matter, sand, earth. Very humid.	50 %. [18, Weber.]	Quality inferior. Not much esteemed. [An excellent variety almost as strong as Para, Weber.] Resin, 9·7 %; ash, 0·8 %.	..
Deep brown inclining to black. Translucid.	The cut rubber is amber-coloured like the bright parts of Para Sernamby.	Odour of methylamine and of mould.	But little vegetable débris or sand.	20 %. 25 to 50 %.	Good elasticity, rather sensitive, somewhat esteemed. Resin, 6·7 %; ash, 2·8 %.	There is another Carthagena rubber of older date, but as it has all the properties of Guayaquil rubber we will amalgamate it with the latter.
Like Para.	Like Para.	Slightly smoky.	Sophisticated with the juice of the *Pindare* and the *Massaranda.*	15 to 20 %, according to the quality.	Rather similar to Para, to the price of which it is alone inferior, under which name it is often sold. Yellow, clean, does not require to be pressed. Superior to coast rubber.	Collection commences in November, ends in April. Tapping is sometimes replaced by felling on Orinoco (baneful results). Mixing of other juices of inferior quality always injurious. Trees ruthlessly destroyed; little rubber now exported.
id.	*id.*	*id.*	Somewhat pure.	15 to 20 %.	Like Para. Resin, 2·2 %; ash, 0·4 %.	Development much neglected, according to Coudreau.
Intense black. Surface granular.	Yellow, which turns slaty grey with age. Very porous.	..	Sand considerable. Water in quantity.	25 to 30 %. [20 to 30, Weber.]	Very elastic; quality esteemed, if not its colour. The Sernambillo (waste) is more esteemed than that of Para; it is less porous, and it contains less water. Resin, 3·6 %; ash, 1·4 %.	Collection commences in August. Felling after tapping. This rubber, when boiled in water, is decolorised, and becomes dirty white. The water, which is tinted, is an energetic purgative.

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

1. American Rubbers—

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
GUAYAQUIL (Sheet).	Ecuador and Colombia.	*Castilloas.*	3 ι. 3 ε. pp. 49 and 51 *et seq.*	Guayaquil.	..	..	Sheets of considerable size, sometimes as large as 1 metre long, 0·5 to 0·7 metre wide, and 0·01 to 0·05 metre thick (say $39\frac{1}{4} \times 19\frac{3}{4}$ to $27\frac{1}{2} \times \frac{2}{5}$ to 2 in.).
GUAYAQUIL and CARTHAGENA (Strip).	*id.*	*id.*	*id.*	Guayaquil and Carthagena.	..	..	Network of 0·10 metre (say 4 in.) in diameter, rarely more. Length varies 3 metres (say 10 ft.) (?).
MEXICO.	Vera Cruz, Taumapilas Tabasco, Guerro, Baraca, Repic Chiapas.	*Castilloa.*	1 α II., and unknown process. p. 45.	..	North America, little in Europe.	..	Sheets of 1 to 4 cms. (say $\frac{3}{8}$ to $1\frac{1}{2}$ in. thick). Length and width 0·5 to 0·6 metre (say 20 to 24 in.). Sometimes in balls or marbles 5 to 6 cms. in diameter (say 2 to $2\frac{3}{8}$ in.).
GUATEMALA.	Guatemala.	*Castilloa.*	3 ι. with *ipomea bona nox.* p. 51.	..	America, little in Europe.	..	Sheets.
NICARAGUA (Sheets), Savanilla, Central America, Costa Rica, Puerto Cabello.	West Indies.	*Castilloa.*	3 ι. p. 51.	..	England, France.	..	Sheets, thickness of 5 mms. to $1\frac{1}{2}$ cms. ($\frac{1}{5}$ to $\frac{3}{5}$ of an in.). Margins often thicker than centre. These sheets are united by meshes into balls, which may weigh more than 100 kilos. (say 2 cwt.).
NICARAGUA (Scraps).	Nicaragua.	*Castilloa.*	2 γ. p. 48.	Greytown.	South America.	..	Sometimes in the form of bladders, which may be as thick as the arm. Sometimes in the form of balls, the smallest of which are as big as the head. Sometimes in bulky blocks of 60 to 80 cubic centimetres. They consist always of more or less attenuated tangles folded back upon and rolled round each other, being sheet cuttings and spontaneously dried tears.

OF COMMERCIAL CRUDE INDIARUBBER.

(2.) CENTRAL AMERICA.

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
Blackish.	Large whitish flakes and lumps in best sorts. On cutting the poor qualities there is found a greenish black, very moist substance, with many vesicles of water.	..	Many earthy impurities. Water in considerable quantities.	20 to 35 %. [30 to 40, Weber.]	Somewhat sensitive and elastic. Little sought after on account of its impurities and variable quality. Resin, 5·7 %; ash, 1·2 %.	The produce of *Castilloa* trees in the Central American States is variously known as Nicaragua, West India, Honduras, Mexican, Guatemala, Panama, and Peruvian "Caucho," according to the locality from which it is obtained. The rubber comes in blocks, sheets, or scraps; is uniformly black, not unfrequently tarry or sticky on the outside, and usually obtains prices about two-thirds of that of the best Para.
id.	Carthagena Strip is a black tough rubber.	..	..	*id.*	*id.*	..
Brown or blackish. Bright amber brown.	Greenish matter; very beautiful horny section.	..	Sand, earth, leaves, sometimes fragments of wood.	12 to 15 %. [30, Weber.]	Very sensitive. Resin, 5·3 %; ash, 1·1 %.	The arboriculture of *Castilloa* is being vigorously and scientifically prosecuted on the Isthmus of Techuantepec, in the district of Soconusco, the State of Chiapas and the State of Vera Cruz.
Black.	When cut, allows a viscous, blackish, very bitter characteristic substance to escape. This liquid, on drying, produces a coat of varnish which easily scales off.	Very characteristic special odour.	Very aqueous.	30 %. [25 to 35, Weber.]	Very sensitive, but little appreciated on account of the resin which it contains, and from which it cannot be freed without injuring the rubber. Resin, 7·2 %; ash, 3·0 %.	Fair average quality rubber.
Blackish.	On cutting, a blackish or greenish yellow substance, and a little brown liquid, with a bitter taste, but not fœtid. The section, on drying, becomes brilliant and black.	Special characteristic odour.	Small quantity of water. Very rarely sand, wood.	10 to 15 %.	The sort most esteemed in Central America. Sensitive, elastic. Rivals Para. Resin, 2·8 %; ash, 1·1 %.	The thinner the sheets the more they are esteemed in trade. The government of Nicaragua has issued a decree giving a premium of 10 cents for every rubber tree planted where the number does not go below 250 planted by one person. The trees must be planted 16 feet apart.
id.	Generally blackish and brilliant, sometimes yellowish, but blackening rapidly with age.	..	Little moisture. Some bits of wood (suber). Sometimes adulterated with sand.	10 to 15 %.	Highly esteemed after Para fin.	..

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
							I. American Rubbers—
GUAYULE.	Mexico.	*Parthenium.*	Crushing of entire shrub and subsequent extraction, possibly by solvents.	New York.	North America, Europe.	..	Black liquorice, tarry tacky masses.
							II. African
SENEGAL, SOUDAN. ..	South Senegambia, Senegalais, Segou, Foutah-Djallou, Samory, Bammako.	*Vahea, Landolphia, Callotropis procera, Ficus khal.*	4. p. 53.	Kayes, Bakel, White Cape.	Marseilles	..	Sometimes in the form of more or less bulky bomb-shaped masses, or in flat sheets of from 1 to 3 cms. thick ($\frac{3}{8}$ of an in. to $1\frac{1}{8}$ in.). Sometimes as pellets obtained by rolling upon itself the rubber got by spontaneous coagulation and drawn out into filaments like Gambia and Mozambique.
CASAMANCA (Boulam).	High plateau of the right bank of the Casamanca.	*Landolphia.*	1 β II. p. 46.	Boulam.	..	..	The same as Senegal rubber.
CASAMANCA (Gambia).	Left bank of the Casamanca.	*Vahea.*	4. p. 53. Sometimes Lemon juice.	Zighinchor.	..	..	Is met with in the form of pellets of from 300 to 800 grammes (say $10\frac{1}{2}$ to 28 oz.), sometimes even 2 kilos. (say $4\frac{1}{2}$ lb.).
SIERRA LEONE (Southern Rivers).	Sierra Leone and Southern Rivers.	*Ficus, Vahea, Landolphia, Diander, Fituma.*	1 β II. p. 46.	Boke, Boffa, Kouakry, Benty, Freetown.	Liverpool, London, Marseilles.	..	Like Soudan, Senegal rubber and Casamanca (Boulam). Balls and sheets.

OF COMMERCIAL CRUDE INDIARUBBER.

(2.) Central America—*continued.*

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
..	..	..	..	..	..	Its black colour and its tacky oleo resinous nature are against it. It can only find a use in admixture as a poor natural substitute for rubber.
Rubbers.						
Reddish brown.	White — slightly rose.	..	Bits of wood. Sometimes earth. Much moisture. Full of sand and dirty bark.	38 %. [25 to 50.] [30 to 50, Weber.]	Inferior quality. Collection process too rudimentary. Resin, 6·1 %; ash, 4·0 %.	Tensile strength high, demand good.
Deep brown.	Greyish, inclining to creamy white, sometimes to rose. Abundant pockets of serum.	Bad.	Much earth and sand.	40 %. [60 %.]	But slightly appreciated.	In March the busiest time of arrival and barter.
White at first, afterwards reddish brown.	Concentric circles varying from brownish red to white (white predominating), which, on exposure to the air, eventually assumes the brownish red colour of the outside. Sometimes black concentric veins alternating with white and rose-coloured veins. The rubber obtained by 3 ι, section bright amber.	..	But little débris. Rather humid.	20 to 25 % (1). 30 to 40 % (2). [15 to 30, Weber.]	Rather nervous quality. Resin, 5·5 %; ash, 2·6 %. First quality valuable; second, inferior.	This rubber, which would be an excellent one if it were not often mixed with latex from different sources, loses its value by these frequent admixtures. The black rubber which is present in it is very tacky, and produces a disastrous effect on the rose rubber. The coagulation experiments with 3 ι, although they gave very good results, have stopped at that. Why? Very nervous. Very elastic.
Dirty reddish brown.	Slate grey; heated to 30°c, pitchy and tacky. Dull.	.	Impurities. Moisture considerable.	23 to 25 %. [Niggers, 10 to 25, Weber.]	Soft, spongy, but little appreciated. Niggers very good. Resin, 6·8 %; ash, 0·4 %. Twist very fair, 20 to 30; Resin, 6·7 %; ash, 0·7 %.	Large tracts of forest land with rubber trees *Landolphia* and *Fitumia*. The most valuable is *L. owariensis*, "Lilibue." The next is *L. florida*, "Nofe," which yields a dark rubber prepared with lime juice. *Fitumia* is estimated in one district alone to be distributed over 600 sq. miles.

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

II. African

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
Liberia.	..	*Landolphia.*	4. p. 53.	Moravia.	..	..	Small-sized balls.
Grand Bassam (Assinia).	Ivory Coast.	*Ficus, Landolphia, Urostigma, Funlumia.*	4. p. 53.	Grand Bassam.	Liverpool, London.	..	Met with in the form of marbles of 1 to 3 cms. in diameter ($\frac{2}{5}$ to $1\frac{1}{5}$ in.).
Accra (Biscuits).	Gold Coast.	*Landolphia.*	3 ϵ. p. 49.	..	London.	..	Small discs.
Niger (Niggers).	Cameroons.	*Landolphia.*	..	..	..	..	Balls sometimes amalgamated together, and then called Block Balls.
Aruwimi, Mongala, Bumba, etc.	Congo.	..	..	..	..	..	Large balls, varying in size like Equator and Lopori.
Lopori.	Congo.	..	..	..	..	..	Balls.
Gaboon (in balls).	Gaboon, Congo.	*Landolphia.*	Unknown.	Ambris.	Antwerp, Rotterdam, London.	..	Very bulky lumps, which eventually assume the shape of the vessel in which they are packed.
Gaboon (Strip).	..	.	Unknown.	..	..	..	Pieces of the size of the thumb to that of the little finger, pressed and stuck against each other, but which do not amalgamate owing to the moisture present.
Equator.	Congo.	..	..	..	..	..	Balls glued to each other.
Uelle.	..	..	..	..	..	..	10–20 lb. slabs.
Congo.	..	*Landolphia.*	2 γ, p. 48, and sometimes 1 β II. p. 46.	Banana.	Antwerp, Havre.	..	Balls or thimbles.
Lower Congo.	Congo, Angola.	*Carpodinus, Clitandra.*	..	..	..	..	Small cubes.

OF COMMERCIAL CRUDE INDIARUBBER.

RUBBERS—*continued.*

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
Brown, white, or black.	White.	..	Moist; adulterated with impurities, vegetable matter, and sand.	25 to 35 %. [20 to 40.] [15 to 25, Weber.]	Rather good quality. Resin, 5·9 %; ash, 1·2 %.	Fair average quality.
Brown.	Deep brown, slightly transparent, some white spots, brilliantly polished surface.	..	Almost no impurities.	20 %. [25 to 35, Weber.]	Firm, good quality, highly commendable. Resin, 7·0 %; ash, 1·0 %.	Marbles or balls are generally an index of good quality. Better sorts highly esteemed.
..	White, veined with red.	..	Earth.	35 %. [30 to 45.]	Not very nervous, passable quality, secondary.	..
Red black.	Red.	..	Very impure, much better recently.	40 to 50 %.	Quality but little esteemed at first, but seems to be getting into favour with consumers.	..
Tacky.	..	Bad; much fermentable matter.	..	Great. [As much as 35, Weber.]	Resin, 5·2 %; ash, 0·7 %.	..
..	..	Putrescible matter.	..	[8 to 16, Weber.]	Resin, 3·3 %; ash, 0·7 %.	..
Brown, slightly tacky.	White, filled with pockets, from which a whitish liquid issues. [Large balls rose blue? or red, small, white, or green.	Nauseous (fermenting nitrogenous matter).	Very moist, but few impurities.	40 %. [30 to 40.] [25 to 35, Weber.]	Sluggish, but little appreciated. Resin, 7·3 %; ash, 0·9 %.	Action of hypochlorite of lime. Large balls strong, small balls weak.
Black.	Spongy white, slate grey, mass; dry section dotted with whitish spots.	*id.*	*id.*	45 %. [35 to 45 Weber.]	But little appreciated. Resin, 11·4 %; ash, 1·8 %.	..
..	..	..	Is not dirty.	6 %.	Resin, 3·3 %; ash, 0·7 %.	Much esteemed.
Dark.	White.	..	..	[7·0, Weber.]	Resin, 5·0 %; ash, 0·9 %.	Very fair average quality.
Black or deep brown.	White, spongy.	*id.*	But little moisture.	40 %. Upper Congo 14 %.	Thimbles more esteemed than the balls. Resin, Upper Congo, 7·7 %; ash, 0·6 %.	The Upper Congo white is in balls, and is highly esteemed. The common contains bark and water, loss 15 %. Congo rubbers coagulated by diluting with 4 to 5 times its weight of water, hence putrescible matter is entrained by the "cream."
Brown or black.	Brown or grey.	..	..	[12 to 35.]	Resin, 8·2 %; ash, 1·2 %.	Average tensile stronger; dry good, wet inferior.

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

II. AFRICAN

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
KASAI (red).	Congo.	..	..	..	..	..	Small red balls.
KASAI (black).	..	..	..	..	..	..	Irregular pieces.
LOANDA (thimbles).	Angola.	..	1 β II. 2 δ. 1 β I. 4. pp. 45, 46, and 53.	St. Paul de Loanda.	Marseilles, Bordeaux, Nantes, Havre.	..	Thimbles or cubes—more or less perfect—with from 5 mms. to 3 cms. of edge, *i.e.* from ⅕ of an inch to 1⅕ inch.
LOANDA (Niggers, or Prima).	Angola.	*Landolphia.*	1 β II. p. 46. 1 β III. p. 46. 4. p. 53.	*id.*	..	..	Balls of 3 to 5 cms. (1⅕ to 2 in.) in diameter.
ANGOLA (Niggers).	Angola.	*id.*	1 β II. p. 46.	..	..	..	Balls of 3 to 5 cms. (1⅕ to 2 in.) in diameter, and more or less deformed.
BENGUELA (agglomerated).	Benguela.	..	..	..	..	..	Pressed balls, amalgamated together.
MOZAMBIQUE (marbles, balls).	Mozambique.	*Vahea, Landolphia.*	3 ε. p. 49.	Natal.	..	..	Balls of rolled thread of 800 grms. to 1½ kilos. (say from 28 to 53 oz.).
MOZAMBIQUE (balls).	..	..	4. p. 53.	..	..	..	Balls, 2 to 4 cms. (say ¾ to 1½ in.) diameter, wound thread.
MOZAMBIQUE (spindles, sausage).	..	..	1 β III. Wound round a core of wood. p. 46.	..	..	..	Spindles, 7 to 15 cms. (say 2¾ to 6 in.) in length by 2 to 4 cms. (say ¾ to 1½ in.) in diameter.
ZANZIBAR.	Zanzibar, Darrar, Central Africa.	*Landolphia.*	..	Zanzibar.	..	..	Like Mozambique balls.

OF COMMERCIAL CRUDE INDIARUBBER.

RUBBERS—*continued.*

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
..	..	..	Clean.	6 to 8 %.	Best from Congo.	Tensile strength high.
..	..	..	Not much sand or wood, but volatile and putrescible matter.	8 to 11 %.	Less esteemed than the red. Resin, 5·7 %; ash, 0·4 %.	..
Slate grey.	Brilliant dry substance, grey, slate-coloured, with numerous white punctures.	Nauseous like Congo, dry.	No foreign bodies; lately a tendency to sophisticate.	15 to 20 %.	Tendency to turn greasy. The most esteemed of the Angola sorts. Resin, 6·6 %; ash, 1·4 %.	This rubber must be stored in a cool place.
Reddish amber brown.	Blonde, horny, translucent.	..	Very few foreign bodies. No moisture (Authors). Very dirty and full of bark (Consul Pickersgill).	8 %.	Very nervous. Highly esteemed.	Tends more and more to disappear from the market, and to be replaced by the following species, called Angola Niggerheads. Some of the more enterprising planters are turning their attention to the cultivation of the rubber plant.
Reddish brown.	Reddish brown on the surface, almost translucent towards the centre. Very soft. Appears to harden after a few days like the skin.	..	Some small vegetable débris. Appreciably moist.	20 %. [18, Weber.]	Not so nervous. More tacky. Resin, 9·0 %; ash, 0·5 %.	Average quality.
..	..	..	Much vegetable débris, sand, and earth. Much moisture.	30 to 50 %. [20 to 25, Weber.]	Very inferior quality. Resin, 4·0 %; ash, 0·6 %.	Much esteemed, if dry.
Deep brown.	Greyish, inclining to cream white.	..	Very moist.	Up to 40 %. [12 to 20, Weber.]	Secondary quality. Resin, 7·9 %; ash, 2·6 %.	The arboriculture of the Ceara rubber tree is being energetically and scientifically prosecuted in plantations on suitable soils by the Mozambique Co.
Sometimes rose, sometimes black.	Rose white section, shining.	..	Moisture, sand, earth.	15 to 25 %.	Rather esteemed, excepting adulteration.	
Sometimes rose, sometimes black.	Red layers and black concentric layers, more numerous towards the centre.	..	Little moisture. Greatly adulterated by vegetable debris and even sand.	18 to 30 %.	Rather esteemed, if it were not adulterated. Resin, 6·4 %; ash, 1·3 %.	..
Like Mozambique balls.		..	Like Mozambique balls.	..	..	..

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

II. African

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
MADAGASCAR (black).	Madagascar, Commores.	..	4. p. 53.	Nossi-Bé.	..	..	Irregularly shaped masses, most generally flattened by the pressure of the package. The lumps vary in size from a man's fist to a human head.
MADAGASCAR (pinky rose).	Madagascar, Reunion.	..	..	Tamatave.	..	..	Round balls.
MADAGASCAR (Niggers).	Madagascar.	..	..	..	..	..	Dark large balls.
III. Asiatic							
ASSAM.	North-west of Bengal (Brahmaputra).	*Ficus, Urceola.*	1 α II. p. 45. 2 γ. p. 48. 1 β III. p. 46.	Calcutta.	London.	In 3 cwt. baskets of split rattans, covered with a gunny bag tied with cane.	Blocks (weighing to 150 grms., say 5 oz.), which strongly adhere to the cloth in which they are packed, to which they stick on account of the greasy state into which this kind of rubber quickly passes.
RANGOON.	Burmah, Annam.	..	..	Singapore, Rangoon.	..	..	Irregular lumps. Similar to Assam.
PENANG and PATANI.	Prince of Wales Island, Malacca, Sunda Isles.	*Ficus, Cynanchum.*	..	Penang.	..	..	Irregular blocks of about 1 sq. decimetre (4 inches).
CEYLON.	Ceylon.	*Hevea, Manihot, Glaziowii, Castilloa elastica.*	Churn or centrifugal.	Colombo.	London.	..	Crêpe block biscuit.
COCHIN-CHINA.	Cochin-China,	*Parameria Glaudulipe.*	..	..	..	..	Clumsy, hard, deep brown lumps.
IV. Oceanic							
JAVA (Lampong).	Sumatra (South-east).	*Ficus elastica.*	1 β III. p. 46.	Singapore.	..	..	More or less bulky cakes, formed by agglomerated sheets.
JAVA (Ben Kalen).	Sumatra (South).	*id.*	..	..	..	..	*id.*

OF COMMERCIAL CRUDE INDIARUBBER.

RUBBERS—*continued.*

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
Black or very deep brown, moist, covered with impuri ies.	White, slightly rose.	..	Earth, gravel, much moisture.	30 to 45 %. [30, Weber.]	Less esteemed than the pinky rose. Resin, 10·4 %; ash, 1·1 %.	The milk of the inferior sorts is coagulated by treatment with salt water or acid, or by artificial heat. The black rubber shipped from Majunga is supposed to be produced by such methods.
Peculiar deep rose red. Smooth like pale horn.	Bright red or rose.	..	Few impurities. Rather moist.	25 to 30 %. [20, Weber.]	Very much esteemed, slightly nervous, rather elastic. Resin, 7·2 %; ash, 0·2 %.	Speciality for moulded articles. Best Madagascar sort, owing to reckless felling and digging up by the roots, likely to be soon exhausted.
..	Brown, white or black.	..	..	25 to 45 %.	Resin, 7·8 %; ash, 2·3 %.	Very variable.
RUBBERS.						
Brown.	Dark, sometimes reddish with white, almost transparent, spots. The rubber is always of a mottled appearance with bright pink streaks.	..	Moisture, sand, earth.	25 to 40 %. [15 to 40, Weber.]	Not much esteemed. Resin, 5·6 %; ash, 0·7 %.	Tending to disappear from the market.
Very dark brown.	Brilliant, marbled with white, blackish red.	..	Always wood.	20 %. [12 to 30, Weber.]	More valued than the preceding. Resin, 4·4 %; ash, 0·7 %.	Cultivated rubber from chonemorpha, macrophylla, Rhyne Wallichi, Ecdysanthera, Micrantha, yield results interesting to planters in further India.
Black on the outside.	Deep brown, bright transparent brown.	..	Earth, sand.	20 to 25 %. [15 to 30, Weber.]	Rather nervous. Resin, 7·6; ash, 1·3 %.	Fair average quality, dry, good. Tacky, inferior.
Straw.	Straw.	Faint.	Nil.	..	Cultivated Hevea rubber, about equal to Para. Superior for waterproofing, but inferior in tensile strength.	Rational cultivation. Recent importation.
RUBBERS.						
Deep brown-coloured tears.	Brown red.	..	..	18 to 30 %. [12 to 30, Weber.]	Little valued, but esteemed, if dry. Resin, 5·6 %; ash, 0·8 %.	Tendency to darken and become tacky in the air and with heat. "Java rubber is similar (to Assam) but usually not so good."—Morris.
Bright blonde-coloured tears.	"Almonds" of red Sumatra gutta percha tears with bluish efflorescence.	..	..	30 to 45 %.	..	..

SYNOPTICAL TABLE OF THE DIFFERENT VARIETIES

IV. OCEANIC

Commercial Denomination.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Port of Shipment.	Commercial Market.	Packages.	Usual Commercial Size and Shape.
JAVA.	Java.	*Ficus elastica.*	..	..	..	..	More or less bulky cakes, formed by agglomerated sheets.
BORNEO (White Assam).	Borneo, Straits Settlements, Celebes, Moluccas, Philippines.	*Urceola, Willughbeia, Dijera, Callotropis.*	3 ε. p. 49. By salt water from ash of leaves of Nipa palm.	Macassar, Singapore.	..	..	Sheets or balls more or less bulky, deformed (callotropis). Sheets varying from 2 to 3 centimetres in thickness, with numerous depressions (other botanical origin).
BORNEO (Djambes).	Sumatra.	*Willughbeia, Leuconotis.*	..	Singapore.	..	..	Balls and sheets
BORNEO (Ben Koclen).	..	..	..	Elock Pura.	..	..	Rather thick sheets.
NEW GUINEA.	..	..	..	..	.. ..	..	Clusters of small balls.
PONTIANAE.	Borneo (West).	..	..	..	..	..	Greyish-white balls.
NEW CALEDONIA.	New Caledonia.	*Ficus prolixa* (Banyan), *Urostigma, Prolixa, Artocarpus, Integrifolia*	1 *a* I. pp. 40 *et seq.*	Port Villa.	Marseilles.	..	Cakes like Para, from 6 to 10 kilos. (13·2 to 22 lb.).

OF COMMERCIAL CRUDE INDIARUBBER.

RUBBERS—*continued.*

Skin or Coat.	Section.	Smell.	Adulteration.	Loss in Industrial Use.	Valuation.	Observations.
Tears of a more decided colour.	The "almonds" more decided.	..	..	18 to 45 %.	Little valued.	
Grey Coat (callotropis). Brown (other botanical origin).	White paste (callotropis). White, often rose or violet tinted (other botanical origin).	Callotropis rubbers have a smell of tanned leather, attributed to the tannin contained in the vine. The other kinds have a nauseous smell, coming from the albumenoids of the latex not asepticised by the tannin.	Pockets with abundant serum. Pockets with abundant serum, frequently sand, greenish clays. Very porous and spongy, the pores being filled with salt water.	25 to 30 %. 35 to 40 %. [35 to 50 Weber.]	Fairly good. Much less esteemed.	Obtained by cutting plant into pieces varying from a few inches to 2 to 3 ft. long, and allowing the juice to drain into buckets, heat being sometimes applied to one of the pieces when the juice flows slowly. The balls of rubber for convenience of carrying are threaded on a strip of rattan.
Reddish brown.	Greenish red.	..	Clay water in quantity.	45 % and more.	Little enough esteemed on account of adulteration.	..
Brown.	White inside.	..	Rather pure.	..	Good quality.	
Black.	Whitish.	..	..	15 %.	Good when free from bark or impurities. Resin, 4·2 %; ash, 1·3 %.	Sometimes a bastard sort is shipped, whitish and hard, almost resembling hard balata.
..	..	..	..	15 %.	Resin, 85 to 95 % ash, 1·8 %.	Highly resinous. Value low.
Brown, inclining to black.	Section veined with white.	Slightly smoky.	Very pure.	18 to 20 %.	Very good quality when free from diverse admixtures. Slightly resinous.	Lately put on the European market.

CHAPTER V

PHYSICAL AND CHEMICAL PROPERTIES OF THE LATEX AND OF INDIARUBBER—GENERAL CONSIDERATIONS

Preliminary Observations—Résumé of previous chapters.—In Chap. I. the general definitions of latex and of rubber have been given, and in succeeding chapters attention has been drawn to the differences in the physical properties and in chemical constitution of these two substances, according to the producing plants, their age, environment of the locality in which they grow, season, and even hour of collection, method of tapping, and, finally, the process employed for separating and getting at the rubber held in suspension in the latex.

From this diversity of circumstances, which may influence one way or another the substance to be examined, arises the absolute necessity of examining the physical and chemical properties of the latex, and of rubber, in a rational and systematic manner. Only one and the same type, therefore, will be examined from the different points of view which the subject involves. Proceeding thus, it is hoped some deductions may be drawn with a really tangible interest, in actual industrial practice; and if some anomaly supervene, it will suffice to point it out. A few examples will explain this scheme.

Adriani's researches on the latex of the Ficus elastica.—Dr. Adriani, author of a monograph on the fresh latex of the *Ficus elastica*, direct from the plant, observed that in a general manner the quantity of solid matter contained in a resiniferous sac was less the higher up the tree the incision was made, and consequently on the younger parts of the incised tree. He experimented on a *Ficus elastica* of about $7\frac{1}{2}$ feet in height. The following are his results:—

Table XVIII.—Showing the Percentage of Solid Matter in Latex according to Height of Incision (Adriani).

Quantity of Latex Evaporated.	Height of the Incision.	Total Residue.	Percentage of Solid Matter.
Kilogrammes.	Metres.	Kilogrammes.	
0·185	0·30	0·046	25·15
0·393	1·74	0·095	24·05
0·143	2·10	0·030	20·98
0·825	2·25	0·145	17·70

Deductions to be drawn from above Table.—Such analytical data are certainly very interesting, and would be more so if experiments had been conducted not only on *Ficus elastica*, but also under similar conditions on other species of rubber trees in general. Some general law could then have been deduced from such experiments as to which was the most advantageous part of the rubber tree to bleed, but at the same time they show us the futility of the summary indication of such and such a manual dealing with this subject, which tells us that the latex yields so much per cent. of rubber without any further particulars.

Example II.—Variations in size of the globules of rubber swimming in the

latex.—Adriani, examining microscopically the latex of the *Ficus*, found that the spherical globules, which constitute rubber, floating in the liquid in great numbers, average 2·3 micromillimetres when the latex is taken from the lower part of the tree, whilst those of the upper part of the tree are 2 micromillimetres. Therefore, in giving the dimensions of the globulites of rubber, the height must be specified at which the latex was collected on the tapped tree, as well as the variety to which the tree belongs.

Example III.—The density of the latex.—Here are three experiments to determine the density of the latex: one on a juice, without any indication either of its origin or of the height of incision; the two others by Ure—one on a latex rich in rubber, the other on a poorer juice.

TABLE XIX.—SHOWING DENSITY OF RUBBER LATEX (MUSPRATT, URE).

	Density.
Muspratt, without indication . .	1·01200
Ure: Latex rather thick . . .	1·01750, say 37 per cent. of gum.
Ure: Latex thinner	1·01121, ,, 20 ,, ,,

Above data as to density insufficient.—Such data cannot facilitate the exact determination of the density of a latex without the comparative results furnished by a fixed and immovable type.

Example IV.—Variations in analyses of latex still more striking.—These differences, and the difficulties which they beget, are still more striking if we compare the analyses of various species of latex. Faraday analysed, in 1826, a *Hevea* latex sent to Europe. Opposite this analysis there is generally placed that given by Adriani, on the laticiferous juice of a terminal bud of *Ficus*.

TABLE XX.—ANALYSES OF LATICES OF PARA AND ASSAM RUBBERS (FARADAY, ADRIANI).

Analysis of a Latex imported from Brazil (Faraday).	Per cent.	Analysis of a Latex of *Ficus* of 2·25 metres, say 7½ feet in height (Adriani).	Per cent.
Caoutchouc	37·70	Caoutchouc	9·57
Albuminous matter . .	1·90	Resin soluble in alcohol but insoluble in ether . .	1·58
Bitter nitrogenous colouring principles . . .	7·13	Organic acids combined with magnesia	0·36
Substances soluble in water .	2·90	Substances insoluble in water	2·18
Wax	0·13	Calcic and sodic salts . .	traces
Water slightly acid . .	56·37	Water	82·30
			95·99

Albuminoids and tannin.—Ure did not find in the two samples of latex he submitted to analysis the albuminous matter determined by Faraday, whilst, on the other hand, he determined the presence of tannin.[1]

[1] I cannot trace Ure having mentioned tannin as an ingredient of latex. He mentions aloetic matter which, if it contains tannin, is essentially different from tannin *per se*. It will be as well to quote Ure textually as follows:—"Having been favoured by Mr. Sevier, formerly managing director of the Joint-Stock Caoutchouc Company, and by Mr. Beale, engineer, with two different samples of caoutchouc juice, I have subjected each to chemical examination. That of Mr. Sevier is greyish brown, that of Mr. Beale is of a milky grey colour, the deviation in whiteness in each case being due to the presence of aloetic matter which accompanies the caoutchouc in the secretion by the tree. The former juice is of the consistence of thin cream, has a specific gravity of 1·04125, and yields by exposure upon a porcelain crucible in a thin layer, for a few days, or by boiling, 20 per cent. of solid caoutchouc. The latter, though it has

Latex of trunk absent from leaves and branches.—Finally, Nees d'Esembeck and Clamor Marquart identified real caoutchouc, as we know it, in the latex of the trunk of the *Ficus*, but not in the branches and leaves of the same plant; the substance which takes its place, and which they call viscine, is only converted later on, according to these two chemists, into indiarubber.

Want of co-ordination in researches.—Such examples could be multiplied, but those given amply suffice to show that if the numerous researches on this subject are full of interesting details, and form precious documents for the history of rubber, they are at least awanting in sufficient co-ordination to deduce therefrom precise and certain laws. It would, therefore, be useful to proceed more methodically, and thus assist those who seek, in a work of this kind, acquired information, from which they may draw proper conclusions. That is the determinant reason which leads us to confine the examination to the physical and chemical properties of (1) the latex of the most highly esteemed rubber-producing plant, and (2) of the rubber which it yields, namely, the rubber to which the trade up to now has given a just preference—the *Hevea braziliensis*—and, as type, a *Hevea* of about twenty-five years old, that is to say, one arrived at the adult age, and thus capable of producing the most abundant and the richest milk. The plant has been incised 0·50 metre (say 19·65 inches) above the soil, the first hour in the day the second month of the dry period of the year 1888 (good average harvest in the Lower Amazon). If in course of such examination we find in the special literature of this subject a fact in flagrant contradiction with the results obtained, attention will be drawn thereto, a work of this nature never having anything absolute about it.

Latex—Physical properties — Colour. — The latex of the *Hevea braziliensis*, collected under the above conditions, has been examined under the microscope. It is a liquid, white to the naked eye, but really colourless, or rather slightly amber-coloured, in which there float quantities of suspended spherical globules, of which the diameter varies, and the average of which is 3·51 μ.[1] These globules constitute the rubber. Colourless in themselves, they impart to the liquid, by their extreme division—whilst each of them still preserves its own individuality,—that white milky aspect which it has not by itself.

Action of air, light, and contact with coloured juices on colour of latex and resultant rubber.—The coloration of this liquid may, however, under definite circumstances, be altered very perceptibly, and so influence the final colour of the rubber which is produced from it. Without mentioning the oxidising action of air and light, the effects of which will have to be studied more especially when treating of real rubber, it is possible that, with rubber trees, other than *Hevea*, the juice, as it leaves the laticiferous tissue, in its passage to the exterior portion of the wound, may have to traverse other tissue containing coloured juices. The colour of the latex, as well as its resiniferous portion, would be appreciably altered.

Morellet's microscopical examination of the bark of the Landolphia—Resinous cells.—Morellet establishes a similar fact whilst studying the *Landolphia* yielding

the consistence of pretty rich cream, has a specific gravity of only 1·0175. It yields no less than 37 per cent. of white, solid, and very elastic caoutchouc. . . . I find that neither of the above two samples of caoutchouc juice affords any appearance of coagulating when mixed in any proportions with alcohol of 0·825 specific gravity, and therefore I infer that albumin is not a necessary constituent of the juice, as Mr. Faraday inferred from his experiments published in the 21st volume of the Journal of the Royal Institution. The odour of Mr. Sevier's sample is slightly acescent; that of Mr. Beale's, which is by far the purer, has no disagreeable smell whatever. The taste of the latter is at first bland and very slight, but eventually very bitter from the aloetic impression upon the tongue. The taste of the former is bitter from the first, in consequence of the great excess of aloes which it contains. When the brown solution, which remains in the capsule after the caoutchouc has been separated in a spongy state by ebullition from 100 grains of the richer juice, is passed through a filter and evaporated, it leaves 4 grains of concrete aloes. . . . The prepared aloetic liquor is not affected by the nitrates of baryta and silver. It affords with oxalate of ammonia minute traces of lime."—Tr.

[1] The $\mu = 1$ micromillimetre, which is the thousandth part of a millimetre.

Mozambique rubber, the microscopical examination of the bark of which he describes thus :—"Several layers of parenchyma are met with on the exterior *p.c.* (Fig. 35), alternating with layers of suber, *s.* Where desquamation has occurred, only the two internal layers are visible. Beneath the extreme internal layer of the suber, numerous sclerose cells, *c.s.*, occur, arranged in radial lines, forming a continuous thick layer generally of from 10 to 20 cellules, then parenchyma, intermixed with numerous branches of sclerose cells, then soft liber, formed from parenchyma, cells

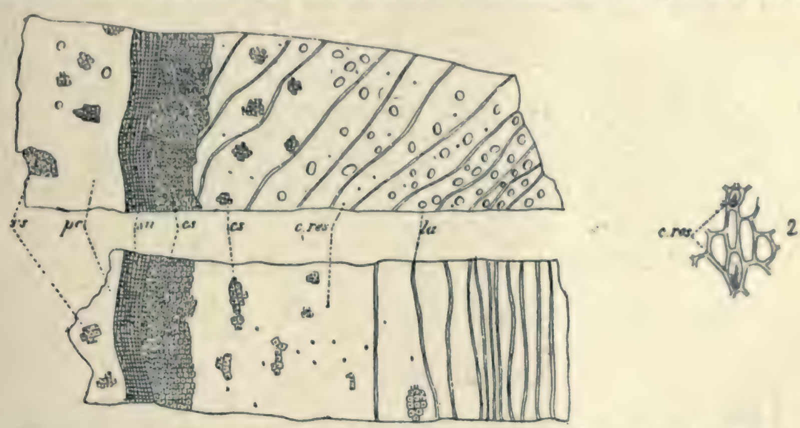


FIG. 35.—1. *Landolphia*, which yields Mozambique rubber ; transverse and longitudinal section of the bark : *c.s.*, sclerose cells ; *p.c.*, cortical parenchyma ; *su.*, suber ; *la.*, laticiferous vessels ; *c.res.*, resinous cells. 2. *c.res.*, detail of the resinous cells in the longitudinal section of the *Vahea* which yields Mozambique rubber.

full of a *red resin*, *c.res.*, possessed of great colouring power, liber fibres small in number, and *laticiferous* vessels in very great abundance." These resinous cells are the cause of the peculiar smell of Mozambique rubber.

Smell.—Fresh *Hevea* latex is inodorous. But when left by itself it rapidly acquires, under the action of the oxygen of the air, a slight smell of methylamine, which again makes itself felt in the rubber prepared from it if it be not sterilised by the smoking process, as occurs with Para seconds, or when a small quantity of

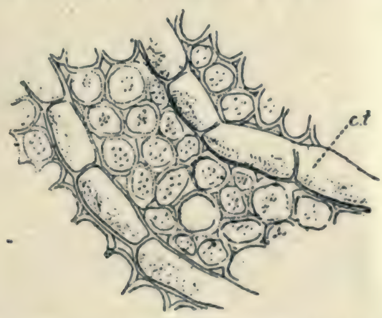


FIG. 36.—Transverse section of the *Callotropis gigantea* : *c.t.*, cells full of tannin.

smoked is mixed with a larger quantity of spontaneously coagulated rubber. This characteristic smell is equally manifest in some varieties of other juices depending upon the intimate constitution of each latex, and its more or less perfect state of preservation.

Taste.—The taste of fresh *Hevea* latex is not very accentuated, rather pleasant and sweet than repugnant and bitter. Carrey says he drank it not without

enjoyment, but the latex must always be fresh, as the taste as well as the smell change quickly in contact with the air. Although this change is not so marked in the *Heveas*, it is very much more decided in the *Hancornias* of Peru and the *Landolphias* of Western Africa. The juice of *Callotropis gigantea* of Borneo owes its slightly bitter taste to a particular astringent substance whose presence has been pointed out by Morellet, in certain cells of the bark of this plant.

Density.—It has already been seen how difficult it is to determine in an absolute and rigorous manner the density of the latex, and how many circumstances intervene to modify the results. *As a general rule, the richer a juice is in rubber the lower is its density, and the higher the density the less will be the amount of rubber therein per unit of volume.* However that may be, the density of the latex here adopted as type is 1·019 at the temperature of 14° C. (57·2° F.), and corresponds to a richness in real caoutchouc of 32 per cent.

Chemical properties — Proximate principles. — In Table XXI. the chemical composition of the latex of the *Hevea braziliensis* at the moment it issues from the plant is given.

TABLE XXI.—CHEMICAL COMPOSITION OF THE LATEX OF THE *HEVEA BRAZILIENSIS.*

	Per cent.
Elastic matter	32·00
Nitrogenous organic matter (putrescible)	2·30
Mineral salts, sodic and calcic (no magnesic)	9·70
Resinous bodies	traces
Water slightly alkaline	55 to 56·00
	100·00

This analysis, which appreciably approaches that given by Faraday in 1826, differs, however, in one interesting point. Faraday's analysis was of a sample of latex imported from Brazil. It had thus taken some time in arriving at the laboratory. Owing to very great liability to decomposition of the vehicle of the rubber globulites, in spite of all precautions in bottling the sample sent, Faraday found an *acid* reaction; whilst on the spot, at the very moment the liquid flows from the incision, it has a slight but decidedly *alkaline* reaction. This ephemeral alkalinity of the latex of the *Hevea* is peculiar, and totally differentiates it from the latex of the *Ficus*, which, as soon as it issues from the producing plant, always appreciably reddens litmus paper. Adriani, who more especially examined the latex of the *Ficus*, attributes the reaction to the presence of a peculiar organic acid, which is distinguished from all other organic acids by its sodic and potassic salts being difficultly soluble in water, whilst the salts which it forms with lime, magnesia, and iron are very soluble. See Table XX.

Nitrogenous putrescible organic bodies in the latex.—Our analysis mentions 2·30 per cent. of *nitrogenous putrescible matters.* This term is purposely used in preference to that of albuminoids or proteid matter. The properties of the substances have not been sufficiently studied, and scientists who have specially examined them are too much at variance as to their nature to justify a definite declaration on the point. They, however, merit very careful examination, for it is undoubtedly to their presence that the great liability of the latex to change, to which we have already referred, is due, and it is almost always owing to their insufficient elimination or neutralisation that commercial rubber owes its most salient defects.

The mineral matter in serum of Hevea latex.—It is unnecessary to dwell particularly on the mineral matters present in the serum of the milk of the *Hevea*, consisting of potassic and calcic organic salts to the exclusion of magnesic salts.

There is nothing abnormal in their presence, and they would be uninteresting if they did not afford an analytical method of assigning, eventually, with some degree of certitude, a true certificate of its origin to any given rubber. Magnesic salts are absent from the mother liquor of the *Hevea* juice, whilst Adriani's analysis shows its presence in every instance in *Ficus* latex. Again, the calcic and potassic salts of the *Hevea* are compounds of two bases with a special and hitherto undetermined organic acid; these two bases are met with in *Landolphia* juice, combined

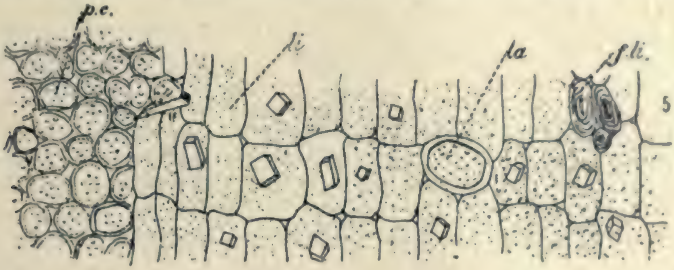


FIG. 37.—Transverse section of *Landolphia gummifera*: *p.c.*, cortical parenchyma; *li.*, liber containing crystals; *la.*, laticiferous vessels; *f.li.*, liberian fibres.

with oxalic acid, and Morellet discovered under the microscope decided crystals of this compound (Fig. 37 *li.*, Fig. 38 *cr.*).

The resinous bodies in the latex.—The traces of resinous bodies in the analysis of *Hevea* latex are for the moment neglectable quantities. They are dealt with under the chemical composition of raw commercial rubber.

Dambonite amylaceous and saccharine principles.—Certain amylaceous and saccharine principles are met with in the latex of the *Hancornias* of Pernambuco and Maranham, in that of the African *Landolphias* and *Vaheas*, and the *Urceolas* of the Malays. Aimé Girard was the first to draw attention to these principles.

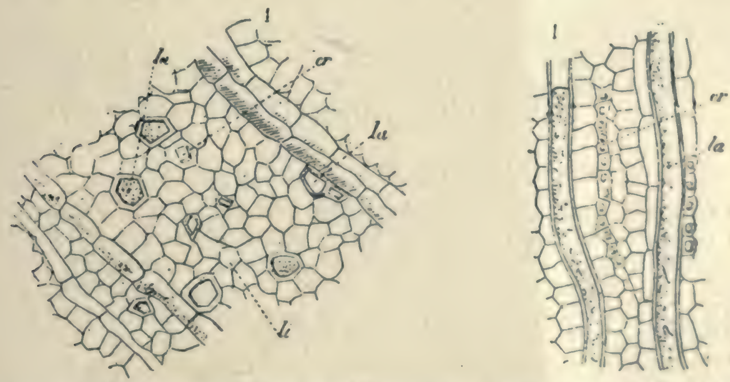


FIG. 38. 1.—Transverse and longitudinal sections of the bark of the *Landolphia senegalensis*: *la.*, laticiferous vessels and latex; *li.*, liber; *cr.*, small cells with crystals.

In his first memoir to the Academy of Sciences in 1868, he says: "The defective process followed in the preparation of Gaboon rubber leaves a white limpid liquid enclosed therein, which changing gradually alters the caoutchouc itself, and causes it eventually to lose all its properties. Owing to these defects, Gaboon rubber requires special and repeated treatment. Before this method was established, manufacturers could not use it, so Gerard and Aubert of Grenelle, being unable to utilise a lot of Gaboon rubber, spoiled by age, resigned themselves to decompose it by heat and convert it into liquid pitch. During the progress of the operation,

and amongst the volatile bodies condensed in the chimney, they observed a white substance, crystallised in fine needles, and possessed of a sweet taste. That is the substance which I have called *Dambonite.*"

Pre-existence of dambonite in the fresh latex itself.—According to Girard, dambonite, a neutral volatile body, pre-exists in the latex itself when it is of recent production. But when the serum has been imprisoned for a long time in the pores of the rubber, it no longer contains the same saccharine substance; it is converted into a gummy body in which there is found, besides a little unaltered dambonite, another non-volatile saccharine body of different composition. In the samples examined Girard collected as much as $\frac{5}{1000}$ of pure dambonite from the caoutchouc analysed.

Properties of dambonite.—It is a white crystalline substance, very soluble in water, readily soluble in ordinary alcohol, slightly soluble in absolute alcohol. It melts at 190° C. (374° F.), and volatilises from 200° to 210° C. (392° to 410° F.) in long brilliant needles. Its chemical composition is indicated by the formula $C_8H_8O_6$.

Hydrates of dambonite.—In presence of water, dambonite hydrate takes up three equivalents of water, which it loses at 100° C. (212° F.). The crystals deposited from a syrupy solution of this hydrate are in the form of highly surbased oblong prisms.

Action of reagents on dambonite.—Dambonite does not reduce cupro-potassic tartrate, is not subject to either the alcoholic or the lactic fermentation; in contact with hydrated acids it is attacked even in the cold; by raising the temperature the reaction becomes more energetic, and at 100° C. (212° F.), in presence of hydriodic acid, or fuming hydrochloric acid, it is complete in half an hour. It then splits up in a remarkable manner, and if the operation be performed in a close vessel, methyl hydriodic ethers are observed to form in the liquid, whilst in the acid liquid there remains in solution a new neutral non-volatile substance, with a saccharine taste, crystallising very well, and presenting the centesimal composition of a dried glucose, *Dambose.*

Chemical constitution of dambonite.—The production of dambose indicates the real composition of dambonite, which cannot therefore be considered, like the greater number of saccharine bodies, as a polytomic alcohol, but as a methylic ether splitting up according to the formula

$$\underbrace{C_8H_8O_6}_{\text{Dambonite.}} + HI. = C_6H_6O_6 + C_2H_3I$$

$$\underbrace{C_8H_8O_6} + HCl. = C_6H_6O_6 + C_2H_3Cl.$$

The author resumes his first work: "The milky juice of the vines secreting Gaboon rubber contains a volatile saccharine principle different in its behaviour and composition from the saccharine bodies hitherto studied. This principle, dambonite, may be regarded as the *methylic ether of a second saccharine principle, dambose*; and this latter, noted for its great stability, evidently belongs to the family of glucoses, and may, like them, play the rôle of a polytomic alcohol."

Borneo dambose and Meteza dambose (bornesite matezite).—It is not necessary to follow M. Girard in the continuation of his researches, by which he was enabled to announce to the Academy of Sciences in 1871 *bornesite* extracted from the *Urceolas* of the Malays, and in 1873 *matezite* extracted from a Madagascar rubber called by the natives *Meteza roritina.* These two products are likewise peculiar methylic ethers of damboses, which the author has styled *Borneo dambose* and *Mateza dambose.* His final conclusions are—

"In comparing the three products," he says, "I have been able to establish in a decided manner the non-identity of the three damboses formed by their splitting up in presence of hydracids, and I have been able to determine amongst their physical properties relations which, coupled with their chemical properties, justify their being considered as the result of the progressively increasing condensation of the same molecule $C_6H_6O_6$."

The following is the résumé of my observations upon this point :—

TABLE XXII.—SHOWING CHEMICAL AND PHYSICAL CONSTANTS OF SUGARS OF THE DAMBOSE TYPE.

Substance.	Formula.	Melting Point.	Rotary Power.
Dambonite . . .	$C_8H_8O_8$.[1]	205°C.	0
Bornesite . . .	$C_{14}H_{14}O_{12}$.	200°C.	+ 32°.
Matezite	$C_{20}H_{20}O_{18}$.	181°C.	+ 79°.
Dambose . . .	$C_6H_6O_6$.	212°C.	0
Borneo dambose . .	$C_{12}H_{12}O_{12}$.	220°C.	0
Matezo dambose . .	$C_{18}H_{12}O_{18}$.	235°C.	+ 6°.

The work of Girard, already very interesting in itself from the point of view of the discovery of a new natural sugar, is of still greater interest to us by the fact that it enables us to give the most plausible explanation of the difference in the behaviour of the rubbers which come from the milk of the *Heveas*, compared with that extracted, as we have just said, from other American, African, and Australasian sources.

If the authors do not quite agree with Girard, in so far that they do not admit the pre-existence of dombonite in the fresh latex yielding the different rubbers which he has examined, it is none the less true that these juices contain a peculiar amylaceous substance, to which undoubtedly must be attributed the baneful influence exerted on the rubbers which are extracted from them, and we are thus enabled to understand how it is that it is necessary to treat these juices in quite a special manner if it be desired to produce a rubber perfectly acceptable to commerce and from which industry may draw every possible advantage. It is by the simultaneous and rational application of heat—natural or artificial—and sodium chloride, and by the complete elimination of the serum residue from the coagulated rubber, and finally by doing it up into very attenuated balls or spindles, that the natural defects of these rubbers may be minimised, which, when well prepared, quickly acquire a greater value, and which are destined to play a more and more important rôle in the rubber industry. Sodium chloride might be very advantageously replaced, in the case of these varieties, by ammonium fluoride, the most powerful antiseptic for stopping the putrid fermentation of amylaceous bodies, if its cost did not tend to debar its use.

Actions of reagents on Hevea latex—1. *Action of water, alcohol, and ether.*—The milky juice is not sensibly altered by the addition of a small quantity of water. In greater proportion the water hastens the separation of the rubber globulites and accelerates the formation of the creamy layer which contains the caoutchouc. Alcohol and ether have an analogous action. Both of these emulsive juices mix readily with water, alcohol, and pyroxylic spirit, although they do not become at all cleaner.[2]

2. *Acids.*—Mineral as well as organic acids, in small proportions, determine the more energetic grouping of the suspended globulites, and thus hasten coagulation.

3. *Concentrated sulphuric acid* causes a great change in the latex—which, however, does not concern us for the moment.

4. *Cold concentrated nitric acid* is without action on the globulites themselves, but it decomposes the serum, in which it produces a gelatinous precipitate. Nitric acid converts it into a red curdy magma.[3]

5. *Concentrated acetic acid* (*glacial*) acts very peculiarly on the globulites in suspension in the latex; at the same time it hastens their amalgamation, causing each of them to swell in a very energetic manner, whilst at the same time they maintain their primitive texture.

[1] ? $C_8H_8O_6$ as on p. 116. All the formulæ and equations quoted from Girard are evidently old notations.—TR.

[2] Ure, *in re* juices, footnote, pp. 111–112.

[3] Ure, *loc. cit.*

6. *Alkalies.*—In contradistinction to acids, alkalies—especially ammonia—hinder the globulites from coagulating, and thus contribute to their remaining in an infinitely divided state in the midst of the liquid vehicle. They develop an amber tint in this liquid, which gradually becomes more and more transparent, whilst the latescent appearance tends more and more to disappear. The property of ammonia of maintaining the rubber globulites in a great state of division or emulsion has often been taken advantage of for preserving the latex, and its conveyance in the natural condition to great distances. A 7 to 8 per cent. solution of ammonia has so been used with success.

7. *Salts—Alum—Chloride of sodium—Fluoride of ammonia.*—Salts in general, but especially antiseptic salts, such as alum, sodium chloride, ammonium fluoride, are powerful coagulants of the different species of latex. They would appear, however, to have a more energetic action on juices of rubber trees other than *Hevea*, on which their action is less marked.

Halogens (*chlorine, bromine, iodine*)—*Sulphur.*—Chlorine, bromine, and iodine must more especially occupy our attention. There need be no question as to sulphur. Its insolubility in ordinary vehicles capable of being mixed with the latex, and its non-volatility at the ordinary temperature, are bound to render its action inefficacious in the liquid media. But it is not so with chlorine, iodine, and bromine. These three bodies, being soluble in water and alcohol at ordinary temperatures, can be brought in contact with the proximate principles of the latex, and it is easy to determine the action which they exert thereon—especially on the rubber globulites—which interest us more definitely and particularly. Under their influence these globulites turn brown, agglomerate rapidly into a very ductile, unique mass, which may be drawn out into long filaments. Their presence has therefore evidently modified the chemical composition of the gummy matter from that which it possessed in the midst of the laticiferous mass: if the substance becomes viscous, that must be attributed to an excess of reagent having been added.

Action of solvents. — The latex will not mix with caoutchine or with petroleum naphtha, but remains at the bottom of these liquids as distinct as mercury does from water.

Action of halogens on the rubber itself.—The action of halogens upon rubber becomes more energetic when it is freed from all the other bodies constituting the latex, the effects produced have a certain analogy with the very singular action of sulphur when it is put in contact with rubber, especially if heat and extreme division aid the metalloid to act more energetically.

Properties of indiarubber—Preliminary observations.—Whilst studying the proximate constituents of *Hevea* latex, we examined each summarily, reserving to the end the essential principle, the ingredient called caoutchouc. It is indispensable to examine a perfectly determined and well-defined body, because, as already mentioned, a certain sample of rubber produced from *Hevea* latex possesses corresponding properties, which another that has been prepared with less care does not possess. The rubber, the structure and different properties of which is about to be considered, is that furnished by the typical latex adopted above, freed from the other proximate constituents, amongst which it was present in the latex by the smoking process, to the exclusion of every other process. To examine and determine its chemical composition and its formula, we shall submit it to the treatment adopted by Payen to obtain a caoutchouc absolutely pure and exempt from all foreign matter.

Preparation of chemically pure rubber.—The rubber known as *Para prima* is cut up into very thin fragments by means of a cutting tool, and is then subjected to prolonged and uninterrupted desiccation in a drying oven. Freed in this way from all interstitial moisture, the substance is digested with five to six times its weight of anhydrous carbon disulphide. When it has assumed a gelatinous, opalescent consistency, 6 per cent. of absolute alcohol is added, which causes the solution to become clear and fluid. Thinned down in this way, the rubber is

filtered through a plug of asbestos, and run into twice its weight of absolute alcohol. The dissolved substance is immediately precipitated to the bottom of the vessel, whilst the carbon disulphide dissolved in the alcohol floats above it. After standing for a sufficiently long time, the liquid is decanted, and the residue washed repeatedly with absolute alcohol until the latter leaves no residue on evaporation. The precipitate is collected, dried at 70° C. (158° F.), and the treatment repeated as before. Chemically pure caoutchouc is finally obtained of density 0·920, at 14° C. (57·2° F.), the elementary analysis of which gives the following results :—

TABLE XXIII.—ULTIMATE ANALYSIS OF CHEMICALLY PURE PARA PRIMA INDIARUBBER.

	Per cent.
Carbon	87·27
Hydrogen	12·73
	100·00

Its chemical formula therefore corresponds to the atomic formula of C_5H_8.

G. Williams' analysis is as follows :—

TABLE XXIV.—ULTIMATE ANALYSIS OF RUBBER (G. WILLIAMS).

	Per cent.
Carbon	86·1
Hydrogen	11·3
Nitrogen	0·7
Ash	0·9
	99·0

Williams cannot therefore have operated on a sufficiently pure sample, and, with this reservation, his analysis only confirms the above results.

As to the chlorides and sulphides mentioned by A. Girard and Cloez, these also have their origin in an impure sample.

TABLE XXV.—ULTIMATE ANALYSIS OF *FICUS* RUBBER (ADRIANI).

	Per cent.
Carbon	78·25
Hydrogen	10·34
Oxygen	11·40
	99·99

As Adriani used a substance which had remained several months above sulphuric acid, and had become quite hard, it can only be inferred that the rubber had become altered, and that his results in no way invalidate those given above.

Constitutional formula. — According to the distillation products of pure rubber, as we shall see further on, it will be convenient to adopt the definite atomic formula of C_5H_8, and thus to consider rubber as a mixture of polymeric carbides of high equivalents, derived from a fundamental carbide C_5H_8 of the class of terpenes or polyterpenes which, under the influence of atmospheric

oxygen and light, partially change into resinous bodies, and thus yield the different rubbers of commerce.

Density.—The density of rubber is generally given as varying between 0·919 and 0·942, and sometimes even the figure of 0·966, as, for example, by Adriani, who especially studied the *Ficus* rubbers. These variations show (1) a very considerable difference between rubbers from different sources, but they also demonstrate very forcibly how necessary it is to use as a starting-point only one and the same type always taken under identical conditions. Chemically pure rubber, prepared by Faraday's method from *Hevea* latex, has a density of 0·919 at the temperature of 14° C. (57·2 F.), and commercial *Para prima* at the same temperature has a density of 0·930. Under the same conditions, all the other varieties have a greater density, which is due not only to a higher percentage of water, but also, more or less, to the organic matter with which this water is charged, and which helps to modify the resultant densities, as well as to the juxtaposition to the pure rubber of a more or less altered substance said to be oxidised.

Density of the commercially purified rubber.—Chapel and Bouquillon made a series of experiments upon this point to determine the specific gravity of different rubbers used in manufacture after these rubbers have been sliced, purified, and dried—namely, when ready to be utilised. These experiments, made at the temperature of 16° C. (60·8° F.), by aid of a very sensitive hydrostatic balance, gave the following results :—

TABLE XXVI.—DENSITY OF COMMERCIALLY PURE RUBBERS READY FOR USE.

Source of Rubber.	Density at 160° C. (60·8° F.).	Source of Rubber.	Density at 160° C. (60·8° F.).
Para . . .	0·914	Sierra Leone . .	0·923
Colombia . . .	0·915	Senegal . . .	0·929
Madagascar . .	0·915	West India Scraps	0·935
Borneo . . .	0·916	Mozambique . .	0·939
Sernamby . . .	0·918	Ceara . . .	0·958
Balls and Negroheads	0·920	Assam . . .	0·967

As rubber contracts and expands, its density varies with the temperature. The specific gravity of the best Para taken in dilute alcohol is 0·914567, of best Assam 0·942972, of best Singapore 0·93650, of best Penang 0·91978.

Physical properties.—The physical properties of rubber cannot be examined on a chemically pure sample, prepared like that used for the study of its elementary composition and its chemical formula. Each time it is dissolved rubber loses a more or less considerable portion of its essential physical properties, and it is necessary, in the examination which follows, to resort to another process in order to obtain as pure a sample as possible. Faraday's method appears the most simple. It leaves intact, as far as possible, the properties of so easily altered a substance.

Preparation of commercially pure Hevea rubber.—To prepare the rubber required for examination, the juice of the *Hevea* is diluted as soon as collected with four times its volume of water, and the mixture allowed to stand, by itself, in a cool place, sheltered from sunlight, for twenty-four hours. The rubber separates as a whitish cream, lighter than the serum. The liquid portion, syphoned off from underneath, is replaced by very cold distilled water, acidulated with hydrochloric acid, and "sharpened" with a little pure sodium chloride, then the washings are continued with distilled water alone, until the wash water no longer contains a trace of any foreign bodies, and comes away perfectly limpid. The mass, consisting of a multitude of small agglomerated fibres, is then collected. Pressure causes water to flow from it, provided that the operation be conducted at a

temperature which does not exceed 14° C. (57·2° F.). The pure mass so obtained is completely dried on pieces of porcelain (shaded from the sun as far as possible) to a white, opaque, elastic pellicle, which, when completely dried in darkness, eventually becomes diaphanous; it remains colourless with a slight amber tint, and possesses all the properties of the best kinds of commercial rubber. It is under this form that the present study of the special physical properties of rubber will be made.

Internal structure.—In the diaphanous condition, rubber, examined under the microscope (an extremely difficult and delicate operation, the substance, owing to its elasticity, doubling up under the pressure of the microtome, and only allowing a slice thin enough to be examined being obtained with difficulty), does not exhibit perceptible vacuities (Wiesner). But Payen, who examined under similar conditions very thin lamellæ of Para rubber whilst still white and opaque, observed numerous irregularly rounded pores communicating with each other, which expand even under the capillary action of liquid and gases, which do not exert a solvent action on the substance. When the permeability of rubber is described, what applications science has been able to make of this porous structure, which is its natural structure, the diaphanous and anhydrous structure examined by Wiesner only being an exception which is occasionally met with in Ceara and Madagascar rubbers, will be evident.

Colour.—Rubber, prepared by Faraday's method, from fresh *Hevea* milk, shaded from sunlight, and at a temperature not exceeding 14 C. (57·2° F.), is diaphanous and colourless when it has been sufficiently dried, and presents a more or less opaque milky aspect when dried at a low temperature. The white, opaque appearance observable on the inside of the section of freshly-cut, recently-prepared rubber is therefore a characteristic sign of a greater or less percentage of moisture, which varies in *Para prima* from 10 to 20 per cent.; but in certain other varieties, owing to defective preparation, the moisture may exceed 50 per cent.

Colour of smoked rubber.—This same rubber recently prepared, but by the smoking process—owing to coagulation by artificial heat—is amber brown, and slightly opaque. Its coloration is due to empyreumatic bodies, and to carbon in an extreme state of division, incorporated by the smoking.

Colour liable to change with age.—The colour of rubber, however prepared, has a tendency to change under the influence of light and atmospheric oxygen. But as not only the colour is altered, but also the chemical composition of the substance itself, the alteration is merely notified here, and will again be referred to under the action of reagents on rubber.

Smell and taste.—Pure rubber, whether prepared by Faraday's process or by chemical purification of commercial brands, is by itself inodorous and insipid. If sometimes commercial varieties acquire the smell and the taste of methylene, of old rum,—if, again, it contracts a fœtid smell, which is often the case with African rubbers,—it is owing to more or less defective preparation and insufficient elimination of the putrescible bodies which accompany it as it issues as latex from the producing plant.

Conduction of heat and electicity.—Indiarubber is generally a bad conductor of heat and electricity. But each different brand possesses this negative property to a more or less pronounced degree, and it is certainly *Hevea* rubber which possesses it in the highest degree. The degree of purity still further exalts it; whilst the change which the rubber undergoes under the action of oxygen, of ozone, as well as light, sometimes diminishes it to such a point that a rubber so altered will conduct very well both heat and electricity. It was thought that use could be made of a covering of indiarubber, lined with esparto, to preserve the steam-pipes of steam-engines against too much loss of caloric. Experience proved that the envelope rapidly lost its protective properties. The same thing occurs in the use of raw rubber in electrical apparatus: excellent at first, they rapidly lose their dielectric value.

Permeability—Payen's experiments in 1852.—(1) "*Action of water.* — The porosity of rubber explains its easy permeability by different liquids which have no appreciable chemical action on it. Water affords one of the most

interesting instances: thin cuttings of dry rubber, one lot from a white, opaque rubber, the other in sheets or foil, slightly yellowish and translucid (that is to say, the one more anhydrous than the other); immersed for thirty days in water, the former absorbed 18·7 per cent. of it, and the latter 26·4 per cent. The first lot increased in length by 5 and in volume by 15·75 per cent. Thick sheets of indiarubber would eventually be similarly penetrated, and a considerable time will be required to completely eliminate it, because the superficial layers, being the first to dry, contract their pores considerably, and thus hinder the final desiccation of the central points. The mechanical hydration ought to be taken into account in commercial transactions, since, by this fact alone, the real value may be diminished from 18 to 26 per cent., and a white shade is only the sign of a purely illusory superior quality. Moreover, the presence of water hinders the penetration of the liquids used in industry to dissolve or swell the rubber, and diminishes its tenacity and its ductility.[1] The apparent whiteness and opacity are generally due to moisture. Complete drying causes the amber coloration and translucency to appear.

(2) *Action of alcohol.*—Anhydrous alcohol easily penetrates rubber, more especially at a temperature of 78° C. (172·4° F.). Dry, thin, translucent slices, heated repeatedly in the liquid during eight days, became opaque, their length being augmented by $\frac{46}{1000}$, and their volume by $\frac{94}{1000}$. Their adhesive properties increase remarkably, even in the midst of the alcohol. Their weight increases in the proportion of 100 to 118·6, and, nevertheless, they cede to that liquid $\frac{25}{1000}$ of a fusible, greasy, fawn-coloured substance. The slices, after the evaporation of the alcohol, were more transparent and more adherent to each other than before this treatment. As far as their tenacity was concerned, it was appreciably diminished."

Dialysing power.—The permeability of rubber also applies to certain gases, without solvent action upon it. These gases traverse it with greater or less facility, according to the state of dilatation of the rubber and the pressure of the gas. Thus Graham, in 1866, used thin sheets of rubber to separate gases, liquefying them in the passage. If a vacuum be made, either in a small satchel of varnished silk filled with thick felt, or in a small balloon filled with sawdust (the felt and the sawdust being intended to support the thin envelope of the caoutchoucised silk or of the balloon), the pellicle of rubber allows a mixture of gases to pass, containing 0·416 of oxygen, and capable of inflaming incandescent wood, whilst air only contains 0·21 of oxygen. The caoutchouc partition therefore retains half the nitrogen, and allows the other half to pass along with the whole of the oxygen. This dialysed air therefore is a gas, exactly intermediate between air and pure oxygen, so far as the question of combustion is concerned. Graham's observations were confirmed by Peyron, who found that atmospheric air, hydrogen, nitrous oxide, carbonic acid, are easily dialysed through natural caoutchouc. Aronstein and Sirks likewise studied this property, in so far as the action of the rubber on carbonic acid and protoxide of nitrogen is concerned. They rendered caoutchouc impermeable to gas, by digesting it for two hours in linseed oil or in a mixture of asphaltum dissolved in tar. Finally, Graham observed that different gases traverse the pores of the rubber with greater or less rapidity, or, in other words, that several gases being in the presence of each other, the volume of each which passed through was variable in the same units of time.

$$N = 1;\ CO = 1{\cdot}113;\ O = 2{\cdot}556;\ H = 3{\cdot}500;\ CO_2 = 13{\cdot}584;$$

CO_2 is thus soluble in thick sheet rubber or tubing; they absorb this gas and swell to ten times their original volume, then, in course of time, the gas is eliminated and the rubber resumes its original volume.

Polarising power.—Wiesner, who analysed numerous varieties of rubber, states that all the species examined by him, without exception, allow light to pass in

[1] The water thus absorbed being eliminated, moreover, but very slowly, it may be conceived that this is a frequent cause of the decay of those rubbers prepared by a too hasty curing of the latex.

magnificent prismatic colours between the Nicols prisms of a polarising microscope. This phenomenon, very marked with greasy rubber, was less so with perfectly dry pieces. The effect of polarisation is better and more decidedly shown if the rubber membrane be strongly compressed between two object-glasses. But the play of colours of thin films possibly intervenes.

Compressibility.—Blossom states that a cube of rubber of 0·88 metre square submitted to a blow of 100 tons diminishes 10 per cent. in volume. This property of natural caoutchouc has been but little studied by specialist writers, whose whole attention in this respect has been brought to bear on vulcanised and mineralised rubber. The subject will therefore be reverted to in more detail when the compressibility of vulcanised rubber is examined.

Expansion and contraction.—Rubber easily expands when heated, and cold contracts it to a corresponding extent. Ure, experimenting on rubber cooled down until it had lost all its elasticity, found it to have a density of 0·9487. Brought back to the temperature of 35° C. (95° F.), that is to say, to the point when the substance regained its normal elasticity, its density had sunk to 0·9259. Under the same volume, the expansion and contraction confirmed these variations in density. The following point is worthy of notice; it is one which has been taken great advantage of by the rubber-thread industry: if natural rubber be heated to 115° C. (239° F.) and then cooled, it loses its contractility during this transition, whilst all its other properties remain intact. A. Gerard utilised this property to obtain thread of extreme tenuity. Having submitted threads which had been stretched to six times their length to a temperature of 115° C. (239° F.), this extension became permanent by sudden cooling, and the threads then lent themselves to a second similar extension. By repeating this experiment five times in succession, the primitive length was increased in the ratio of 1 to 16625. The diameter was diminished in proportion to this enormous elongation, and the threads were obtained in a degree of fineness hitherto unknown. With expansion and contraction two other properties of indiarubber are closely connected:

Elasticity and extensibility.—Of all known solid bodies, rubber has the greatest degree of elasticity, *i.e.* the property of being but little capable in the natural state of preserving in a permanent manner the changes of shape which a mechanical force may impart to it. A ball cut out of a block of *Para prima*, falling with only the velocity imparted to it by its own weight, rebounds from the ground, and rises to a height varying between one-half and three-quarters of the course traversed in its fall. From the summit which it reaches it falls again, to rise once more, and it continues thus to rebound until, the oscillations getting more and more reduced, on account of the using up of the effort imparted to it in overcoming the resistance of the friction of the ground, it finally stops. But, besides *elasticity*, rubber possesses the property of *extensibility*, *i.e.* of supporting an elongation which, in a band of natural *Para prima*, may amount to five times its primitive length without breaking, then of regaining very rapidly, if left to itself, its primitive dimensions, unless a new force intervene, *e.g.* alteration in temperature. Gerard observed that fibres elongated to the extent of six times their original size could again be elongated to the same extent if exposed to a temperature of 108° C. (226·2° F.). This extensibility may be brought into play in any direction with the same facility, and rubber may be temporarily deprived of its elasticity: if, for example, after having strongly stretched a band of this substance, it be rapidly cooled, it loses its elasticity, and may remain stretched indefinitely without recovering it. It suffices to moisten this band and to evaporate the water by agitating the air.

The rubber soon regains its elasticity if it be subjected to a temperature of +22° C. (71·6° F.). But if it be deprived of its latent heat by compression, it may be exposed even to 26° and 27° C. (78·8° and 80·6° F.) during several weeks without reverting to its normal condition. When successive portions of indiarubber thread, deprived of its elasticity, are pinched with the fingers, a strong contractile force operates exclusively in these points, without the untouched portions altering

their texture; the thread then assumes the appearance of a string with knots, and it can preserve this condition for an indefinite time if it be not manipulated and if it be kept at a moderate temperature. The different intervals between the swellings do not change their properties, and thus show that the latent heat has no tendency to diffuse itself or to equalise itself in the mass. If an indiarubber band, deprived of its elasticity, be held in the palm of the hand, a slight feeling of cold is produced, which proceeds from the rapid absorption of heat by the elastic substance. This peculiarity is eminently characteristic of native rubber, and is hardly observable in that prepared by one of the following methods:—(1) Solution in spirits of turpentine, followed by drying. (2) The mastication of the raw material until it forms a paste, which is connected into sheets between two heated rolls. Para rubber, in preference to any other, lends itself marvellously to this experiment. In 1840, another method was adopted to deprive rubber of its elasticity. In the manufacture of elastic fibres it is, for the moment, indispensable that the threads lose their elasticity, to render any further transformation possible. To effect this, it is wound on a reel, turned rapidly by a workman, whilst another workman conducts it to the reel, keeping it stretched so as to impart to it in the stretching seven or eight times the length it formerly had. The threads are then left in this state of tension during two or three weeks, after which they are so far deprived of elasticity as to be capable of being wrought without thereby regaining their original length. But it suffices to expose them to heat, even to rub them between the palms of the hand, for them to regain their primitive elasticity. Sudden, abrupt extension of rubber gives rise to considerable disengagement of heat, and Brockedon raised the temperature of 30 grammes of water 2° C. (3·6° F.) in fifteen minutes by collecting the heat produced by the abrupt tension of an indiarubber thread. Elasticity, which may be augmented by a slight elevation of temperature, disappears about 3° to 4° C. (5·4° to 7·2° F.) above +0° C. (32° F.), below which rubber becomes rigid like old leather, but not brittle; it is frozen, and does not regain its original properties until it is exposed to a temperature of +40° C. (140° F.), or unless it be drawn out and compressed alternately.

Adhesion.—At the ordinary temperature natural rubber is soft and so viscous that two sections of the same fragment of rubber, when placed together and slightly pressed, adhere with such tenacity that they appear to consist of a single compact piece. This property increases with rise of temperature, whilst it so decreases on cooling that below 0° C. (32° F.) the cut surfaces no longer unite. This subject will be further discussed when treating on the action of reagents, chiefly sulphur, on rubber.

Here terminates the brief examination of the physical properties of raw rubber. It could have been dwelt upon further, the subject is so interesting from many points of view. But although the plan of this treatise does not allow of too many details, the subject will again be reverted to on several occasions, when vulcanised rubber is discussed. A special paragraph could also have been allotted to the permeability of this substance to liquids and gases, but this property belongs more especially to the chemical part, which now falls to be discussed.

Action of chemical agents—Heat—How rubber melts.—Pure as well as commercial rubber, when heated, becomes gradually more pliant and elastic, but at about 145° C. (293° F.) its state of existence is modified, it becomes viscous, it adheres to hard bodies, it gives way and loses its elasticity. Towards 170° to 180° C. (338° to 356° F.) it finally melts into a thick liquid, very similar to molasses, and does not regain its primitive properties until after a very long time, and then only but partially and in very feeble proportion. It is then almost black, tacky, and viscous; it has turned "fatty." At 220° C. rubber becomes oleaginous, and decomposes at 300° C.

How it burns.—Rubber, so altered in contact with an ignited body, burns with a very smoky red flame. When in fairly sized blocks, it may be easily extinguished, but if it be in fragments (factory waste-cuttings), the heat is rapidly propagated, the whole melts, and it becomes almost impossible to stop the fire.

Destructive distillation of rubber.—On destructive distillation rubber generates several products: in the beginning it only disengages a little carbonic acid (CO_2) and carbonic oxide (CO), with traces of some other products the exact nature of which it is almost impossible to determine, and in which Gerard and Cloez thought they encountered sulphuretted hydrogen and hydrochloric acid. In the variety taken here as type these bodies were not detected. At this point it is necessary to raise the temperature, so as to "boil" the rubber, which then gradually disappears without leaving an appreciable residue, giving birth to several hydrocarbides which possess the property of dissolving with facility sound rubber, amber, copal, etc. As a considerable proportion of them are obtained, it was proposed a long time ago to utilise the most volatile fractions for the treatment of indiarubber and in the preparation of various varnishes (Barnard, 1833).

The hydrocarbides produced by the destructive distillation of rubber.—The hydrocarbides generated during the dry distillation of rubber have been examined by Gregory, Dalton, Himly, Greville Williams, Bouchardat, and Sir W. Tilden, Carl Otto Weber, etc.

1. *Volatile hydrocarbides light spirit.*—According to Bouchardat, the most volatile portions of the distillation of indiarubber collected in a freezing mixture consists of *butylene* (C_4H_8), caoutchène, and eupione. Caoutchène, isomeric with butylene, boils at 14° C. (57·2° F.); its density is 0·660; it congeals at 10° C. (50° F.) in the form of needles.

Himly.—Rubber on distillation yields charcoal and three-quarters of its weight of a volatile thick dark oil which when redistilled yields a fraction between 130° and 205° C., which is resolved on redistillation into a fraction. The density of the most volatile portions of which collected by Himly is 0·654; they boil between 33° and 44° C. (91·4° and 111·2° F.). By treating them by concentrated sulphuric acid they are (Gregory) transformed into isomers, boiling at 220° C. (428° F.).

Greville Williams—Isoprene.—The more recent researches of Greville Williams show that after several rectifications over sodium a light body can be extracted from these oils, to which he gave the name of *isoprene* (*hemiterpene*), boiling at from 37° to 38° C. (98·6° to 100·4° F.), with a density of 0·6823, and a vapour density of 2·40. The same hydrocarbide is produced by the distillation of gutta percha. Exposed to air, it absorbs oxygen, and is converted into a white solid amorphous body.

2. *The heavier oils from the dry distillation of rubber.*—The less volatile fraction contains a hydrocarbide (Himly's *caoutchine*), which is obtained pure by treating the crude oil with sulphuric acid, diluted with eight times its weight of water. After washing with water, and a distillation over potash, it is saturated with hydrochloric acid, and afterwards dissolved in alcohol. By diluting the alcoholic solution with water, an oil is precipitated, which, dried over calcium chloride and rectified several times over baryta, then over sodium, presents the following properties:—

Properties of caoutchine.—Density = 0·842. Vapour density = 4·461. It is polymeric with isoprene, and should be represented by the formula $C_{10}H_{16}$; it boils at 170° C. (338° F.), and does not become solid by a cold of − 30° C. (− 22° F.); it is insoluble in water, and easily dissolves in alcohol and ether, essential and fatty oils; hydrogen peroxide resinifies it. It is attacked by chorine and bromine. Chlorocaoutchine is viscous; its density = 1·443; it decomposes when distilled over a base, and yields a hydrocarbide containing more carbon than caoutchine. It combines directly with hydrochloric acid, and with hydrobromic acid; the hydrochloride of caoutchine, isomeric with the solid "artificial camphor" of spirits of turpentine, is a brownish oil, with a nauseous taste. Density = 0·950. It is decomposed on distillation, and is not attackable by dilute alkalies. Concentrated sulphuric acid transforms caoutchine into a thick oil resembling hevéène, whilst a small quantity of a sulphoconjugated acid is produced at the same time. By treating caoutchine alternately with bromine and sodium, two atoms of hydrogen are abstracted from it, and it is converted into *cymene* ($C_{10}H_{12}$):—(G. W.).

3. *The heaviest oils from the dry distillation of rubber.*—Finally, the heaviest portions[1] of the distillation of rubber contain an amber-yellow oily hydrocarbide, of a bitter taste, to which Bouchardat has given the name of *hevéène*, and which is isomeric with ethylène. Density = 0·921 at 21° C. (71·6° F.). It boils between 315° and 350° C. (599° to 662° F.); it does not solidify on cooling, is soluble in ether, alcohol, fatty and essential oils. It absorbs chlorine, and then assumes a waxy consistency. It is decomposed on boiling and resolved into gaseous and liquid products, the latter of which have a lower boiling point. Sulphuric acid resinifies it and transforms it into an oil boiling at 228° C. (442·4° F.), which is not attacked by concentrated acids. Bouchardat concluded, from the manner in which the different products of the distillation of caoutchouc behave, and more especially isoprene, that all these products, like caoutchouc itself, are polymers of isoprene.

Synthesis of Indiarubber.—Bouchardat's researches.—Pushing these studies further forward, Bouchardat claimed to have obtained artificial or synthetical rubber by causing hydrochloric acid to react on isoprene. But his claim has never been absolutely substantiated nor confirmed by any other independent authority. One part of this body mixed with 15 parts of saturated hydrochloric acid was subjected, in a sealed tube, to the action of a freezing mixture. As soon as the tube containing the mixture was agitated, a violent reaction was produced, accompanied by an abundant disengagement of heat. The mass obtained is abandoned to itself for two to three weeks at the surrounding temperature, and care is taken to agitate it from time to time. If the product then be subjected to distillation after having been previously diluted with water, there is obtained, besides a monohydrochloride and a dihydrochloride of isoprene, a solid residue which, freed from the chlorides formed, by prolonged washing with boiling water, presents the following composition:—

TABLE XXVII.—ANALYSIS OF BOUCHARDAT'S SO-CALLED SYNTHETIC RUBBER.

	Per cent.
Carbon	87·1
Hydrogen	11·7
Chlorine	1·7
	100·5

Bouchardat does not consider the presence of this latter body but as accidental, and due to a residuum of chlorides from which it is difficult to free the mass. It is therefore, he claims, a substance analogous with indiarubber, insoluble in alcohol, and which swells in ether and carbon disulphide.

Submitted to dry distillation, this new substance produced the same hydrocarbides as indiarubber, and Bouchardat concluded therefrom that his product was identical with natural rubber. But J. G. M'Intosh, in his efforts to deprive pinene hydrochloride of its HCl (British Patent), always obtained a small quantity of a rubber-like residue, distended by alkaline lye, which was left in the steam- or fire-heated copper still at the close of the operation. He has no doubt that this substance is identical with that obtained by Bouchardat. When freed from the alkali and salt, with which it is distended, the highly swollen elastic pitch-like body decreases to a minimum, and loses its elasticity and crumbles to a powder. This "synthetic rubber" possibly comes from the free resinous acids in the turps, etc.

Sir W. A. Tilden's researches.—Tilden, resuming the researches of Bouchardat,

[1] Obtained by distilling rectified caoutchine with water as long as any part of it passed over with the aqueous vapour, and then redistilling the residue in an oil bath.

recognised in 1884 that isoprene was also found in the most volatile portions of the distillation of turpentine, and of certain vegetable oils, such as colza oil, linseed oil, and castor oil. Isoprene, thus obtained, in contact with saturated hydrochloric acid, was also converted into a solid elastic mass similar to indiarubber. During the course of his 1891 experiments, Tilden, after having separated isoprene from different vegetable oils, studied its properties attentively. Each particular specimen was enclosed in a flask and put to one side in the laboratory, and at the end of a few months he found that the substances in the flasks were completely altered in appearance and properties. The liquid, originally limpid and colourless, had become converted into a syrupy mass, in which there floated rather bulky yellowish lumps. These, on further examination, he found to possess all the properties of caoutchouc, and attributed this formation to the generation, by oxidation, of a small quantity of acetic or formic acid. These acids, in their turn, induced the transformation of the remainder of the mass, probably by fermentation. The liquid then contained a little unaltered isoprene, slightly acid to test-paper. Analysis showed that the solid substance, which floated on the surface, was a product possessing all the constitutive elements of natural rubber. Like the latter, it consisted of two substances, the one more soluble than the other, in such vehicles as benzol and carbon disulphide. The evaporated benzene solution yielded a residue having all the characteristics of the residue of a benzene solution of *Para prima* rubber, evaporated in the same conditions, the same elementary composition, the same adhesive and elastic properties. There is no need to insist upon the importance of the researches of Bouchardat and Tilden — synthetically-produced rubber has passed into the domain of facts. So far as the industrial question is concerned, the production costs relatively a little high. In regard thereto, there is no reason to doubt the sagacity of our investigators. Bouchardat experimented on a derivative of indiarubber itself. Tilden operated on derivatives of spirits of turpentine and of vegetable oils. Further advances will be made, and it would not be surprising if in the near future natural rubber had to compete with the synthetical variety. Certain manufactured samples leave absolutely nothing to be desired so far as quality is concerned, whilst, as to the price, it is a matter of time and patience ; the subject is worthy of being probed to the bottom, for although only a rubber of uniform quality has hitherto been obtained, it is at least free from all impurity, which is not the case with natural rubber.[1]

Action of solvents on normal rubber.—Insolubility in water.—If water and alcohol penetrate rubber and cause it to swell, they do not dissolve it, neither when hot nor when cold. Certain sorts cede to water a feeble quantity of extractive matter ; these are the substances which Muspratt (? Ure) called aloetic, and which come, almost always, from certain juices added to the latex to hasten coagulation. Certain raw rubbers from Peru, whilst being wrought in the factory make the workers engaged in the first stage of their manipulation ill. After being boiled, these almost black rubbers come out of their bath amber-coloured and inoffensive, whilst the strongly-coloured deep brown water is changed into a rather violent purgative. But the pure rubber now under examination is absolutely insoluble in that vehicle.

Insolubility in alcohol.—It is likewise insoluble in alcohol, and, if sometimes certain rubbers on being treated with boiling alcohol cede to it about 2 per cent. of a greasy amber-coloured fusible body, it is because they have been subjected to the oxidising action of air and light, an alteration which will be discussed when the influence of atmospheric agents on caoutchouc falls to be considered.

Other solvents.—Ether, carbon disulphide, light coal-tar naphtha, petroleum, spirits of turpentine, fatty and essential oils, several mixtures of these with other

[1] The authors are more sanguine than what has been done in this direction *up to now* justifies.—Tr. [The above remark was criticised in certain quarters when the first English edition appeared in 1903. Time has justified the remark.]

liquids, and, finally, according to Kletzinski, even boiling naphthaline, insinuate themselves rapidly, like water and alcohol, into the pores of the caoutchouc, causing it to swell enormously, and apparently to dissolve it. But what is often regarded as complete solution in such cases is only in reality the result of the interposition of the dissolved portion in the very swollen portion, the latter having preserved the primitive form, greatly enlarged, and being therefore easily disaggregated.

Separation of the soluble and insoluble portions.—We can therefore, by the aid of a sufficient quantity of each solvent, almost completely separate the two portions by renewing the liquid without agitation and without disaggregating the greatly swollen but undissolved residue. The easily dissolved portions vary between 3 and 7 per cent., with the quality of the samples and the nature of the solvent, but the properties of the two portions remain distinct after their separation and evaporation of the liquid solvent.

TABLE XXVIII.—SHOWING SOLUBILITY OF INDIARUBBER IN VARIOUS SOLVENTS (TSCHIRSCH).

		A.	B.	C.	D.	E.	F.
Para	Soluble	54	45	62	51	59	63
	Insoluble	45	52	31·3	46	39	33
	Water	1	3	6·7	3	2	4
Para Masticated	Soluble	76	73·8	75	64	71·5	96·5
	Insoluble	22	20·8	24·5	35	25·0	0·5
	Water	2	—	0·5	1	3·5	3·0
African Medium Batanga	Soluble	94·0	94·0	94·0	85·5	92·0	94·0
	Insoluble	3·0	3·0	2·0	9·5	3·0	3·0
	Water	3·0	3·0	4·0	5·0	5·0	3·0

A, B, C, D = Petroleum ethers of different boiling-points: A, boiling-point over 60° C. B, boiling-point under 60° C. C, boiling-point over 60° C.; the rubber was then treated with alcohol. D, boiling-point under 60° C.; the rubber was then treated with alcohol. E, benzol boiling between 35° and 110° C. F, chloroform.

Their different properties.—The undissolved portion is less adhesive, but more tenacious; it retains the greatest part of the brown colouring principle of the commercial varieties. The soluble portion, more especially that first dissolved, is decidedly more adhesive, softer, more elastic, less tenacious, and less coloured. Anhydrous ether extracts from translucid rubber of an amber colour 66 per cent. of a colourless soluble substance, and leaves 34 per cent. of a fawn-coloured body. Anhydrous and well-rectified *spirits of turpentine* separates distinctly from commercial brown-coloured varieties of rubber 49 per cent. of soluble amber-matter, and 51 per cent. of translucid insoluble matter retaining the brown coloration. The *ether* solution of rubber is precipitated by alcohol, yielding a milky emulsion analogous to the natural juice of the latex. *Heavy coal-tar oils* dissolve 5 per cent. of their weight of caoutchouc, whilst the *light oils* dissolve as much as 30 per cent. *Only the most highly volatile solvents used in the industry.—The best solvent,* according to Gerard, is a *mixture of* 100 *parts of carbon disulphide and* 5½ *per cent. of absolute alcohol.* A clear solution like water is claimed to be obtained with this mixture, which on evaporation leaves the indiarabber under the form of an extremely thin and pure pellicle (British Patent, 13,069; 1850). Gerard, being specially engaged in drawing rubber out into cylindrical threads, prepared the paste by using carbon disulphide, mixed with 5 per cent. of ordinary alcohol.

This alcohol, containing 15 per cent. of water, hinders solution, and conditions are thus realised for a swelling of the rubber favourable for kneading, and which facilitates the passage to the draw-plate without effecting real solution, which would much diminish the tenacity. Generally, rubber solutions yield on evaporation a pitchy, tacky residue; the slower the evaporation the more do these properties manifest themselves. In industry, therefore, only the most volatile solvents are used.[1]

The nervous and adhesive principles of rubber.—Solution in above vehicles is thus only partial. Rubber, in fact, consists of two isomeric substances, one of which, solid and elastic, resists almost all reagents; the other, semi-liquid and tacky, is much more easily attacked and dissolved. It is to this second body that rubber owes its property of soldering itself to itself when its recently cut surfaces are strongly compressed. To the first body the name of *nervous principle* is given, and to the second the term of *adhesive principle* is applied. If these two isomeric proximate principles be separated by appropriate solution, neither of them preserves the elastic and extensible properties to the same extent. "It would appear," says Payen, "that the adherence between the lubricated filaments by a greasy body, rendered supple by the soluble and soft portion, had been partially destroyed." If indiarubber, cut into the form of rectangular prisms, be kept immersed in a large excess of solvent, it will be seen to swell gradually from the superficies to the centre. *The augmentation in volume* of the undissolved portion may be determined. When the swelling is finished, the dimensions of the sides are tripled in benzine, anhydrous ether, spirits of turpentine, as well as in a mixture of 100 of carbon disulphide with 4 of hydrated ether. The total volume therefore was equal to twenty-seven times the original volume, even though this increase only applied to the undissolved portion, the soluble portion being diffused in the liquid. A mixture of six volumes of ether with one volume of alcohol swells caoutchouc so as to quadruple its volume, but only appreciably dissolves the less nervous and most adhesive portion. In cold, rectified petroleum oil, an increase of thirty times its volume has been observed, but without taking the dissolved portion into account.

Microscopical examination of the swollen insoluble portion of rubber.—If the portion of rubber most resistant to solvents be examined under the microscope with a magnifying power of 300, it shows a reticulated texture, the anastomosed filaments of which stretch and swell, absorb the above liquids, and contract proportionately as the operation goes on.

Parkes' solvent—Thiocamf.—Parkes patented, as an excellent solvent for caoutchouc, the liquid obtained by passing a current of gaseous sulphurous anhydride over camphor (British Patent, 11,147; 1846). See also Professor Emerson Reynold's Thiocamf (British Patent).

Caoutchoucene.—The liquid hydrocarbide obtained by the distillation of caoutchouc is an energetic solvent. But it and the preceding are too dear to permit of actual use.

The extent to which rubber dissolves in benzol.—Heeren determined the solvent power of benzol on twelve principal varieties of commercial rubber. The samples, continuously kneaded by hot rollers, were afterwards cut into strips thin enough to be placed in small flasks, and then drenched with a sufficient quantity of benzol to completely moisten them. After sufficient digestion, enough benzol was gradually added to convert all the samples into a syrupy consistency by frequent agitation. He thus got an equal degree of liquefaction with all the samples tested. A small portion of the liquid so obtained was taken from each sample, weighed on tared watch-glasses, and evaporated in the drying-oven

[1] The translator in the first edition of Livache and M'Intosh's "Varnishes," recommended warm liquid terebinthine (pinene) hydrochloride—an artificial camphor residual—as the best solvent for rubber. It is the only solvent which he has found to act visibly and energetically. Possibly this is the rubber solvent referred to as terpineol by W. F. Reid. It is difficult to see how terpineol can be an artificial camphor residual.

until the benzol had completely disappeared. The following table gives the results :—

TABLE XXIX.—SOLUBILITY OF COMMERCIAL RUBBER IN BENZOL (HEEREN).

Variety of Commercial Rubber.	Percentage of Rubber in Solution.	That is to say, 100 Parts of Benzol dissolved.
Guayaquil	20·0	25·0
Para	17·0	20·0
Carthagena	16·1	18·0
Borneo	13·8	15·0
Africa	12·7	14·5
Ceara	12·0	13·6
Mozambique	11·5	13·0
Quisambo	9·1	10·0
Rangoon	9·0	9·8
Knikels	8·6	9·4
Niggers	7·8	8·5
Madagascar	5·8	6·0

A very curious conclusion may be drawn from Heeren's results. The figures given in the above table show a very marked solubility in the case of Para rubber, whilst Madagascar rubber only indicates an excessively poor relative solubility. Nevertheless, both of these species of rubber are *varieties preferred and sought after* in commerce and industry, each for special applications. Obviously the two rubbers are not esteemed for the same reason, and are not utilised in industry for the same purposes, the one containing more nervous matter and the other more soft and adhesive substance.

General remark applicable to all varieties of rubber and all solvents.—Both solvent and rubber should be exempt from water or moisture within the limits of the possible ; if it only be desired to soften the rubber without dissolving it, hydrated solvents are preferable.

Action of atmospheric agents—Modifications in colour and chemical composition—Miller's experiments.—Atmospheric agents exert a very decided action on natural rubber. Both air and light alter the colour of rubber, and the longer rubber is exposed to these agents the more the colour is accentuated. Not only is the colour changed, but the proximate principles constituting the substance are likewise modified.

TABLE XXX.—PERCENTAGE OF OXYGEN IN DIFFERENT PORTIONS OF PLANTATION RUBBER FRACTIONALLY SEPARATED THEREFROM BY SOLUTION IN PETROLEUM ETHER (FENDLER). (See TABLE XXXVIII.)

	Oxygen in Portion Soluble in Petroleum Ether.	Oxygen in Portion Insoluble in Petroleum Ether.
	Per cent.	Per cent.
Ceylon Para	2·66	17·00
Togo Manihot	5·48	26·09
East African Manihot	...	25·8

Miller made interesting experiments on this subject. He exhausted, by benzine, a piece of goods waterproofed by indiarubber, and which in that state had remained during six years in contact with the air. Benzine only partially dissolved the rubber, and the dissolved product left on evaporation of its solvent possessed altogether new

properties: it resembled shellac; it dissolved in alcohol, chloroform, benzol, and alkaline solutions, but was insoluble in spirits of turpentine, carbon disulphide, and ether; on distillation it yielded water, which proved it to contain oxygen. The author gave its composition as—

TABLE XXXI.—SHOWING ULTIMATE ANALYSIS OF RUBBER EXTRACTED FROM WATERPROOF GOODS AFTER SIX YEARS' EXPOSURE TO AIR.

	Per cent.
Carbon	64·0
Hydrogen	8·46
Oxygen	27·54
	100·00

This alteration, much more rapid in the case of normal caoutchouc than in that of the natural rubber, is more apt to take place when it is exposed alternately to air, to the sun, and to moisture. The substance then acquires a penetrating odour, and it becomes at the same time soft and less resistant (Payen). Vulcanisation impedes this alteration or rather transformation (Warren de la Rue and Abel). The action of light on natural rubber is very singular, and has been taken advantage of technically. If a sheet of rubber be exposed to sunlight for a few hours, the surfaces exposed, laid on, and pressed on to a lithographic stone, it communicates to the latter the property of assimilating lithographic ink, which is not the case with the portions which have remained in the shade. If a layer of indiarubber, dissolved in benzol, be spread upon paper, and if after evaporation of the solvent this sheet be exposed under a negative, it may then be laid on a lithographic stone and used to make very delicate reproductions. This property is utilised in photolithography. The action of air, in absence of light, would appear to be less energetic, especially during a more or less prolonged period. If the action of heat be combined with that of air and atmospheric oxygen, the alteration is more appreciable, and light is not even indispensable. Chapel examined a sample of decomposed Accra rubber. It appeared to the naked eye as a sticky substance, but microscopic examination showed that decomposition was only partial; the soft substance had been attacked, but the nervous part had resisted alteration more energetically.

To determine why rubber perished, L. Clark tested *natural Para prima* (*A.*) against *normal Para sheets* (*B.*). Here are the results as given in the *Moniteur Scientifique de Quesneville*, March 1872. (*A.*) *Natural Para prima.*—One ounce (31·35 grammes) of rubber was used in each experiment. The rubber was in the form of a narrow ribbon, drawn out while hot, and suddenly cooled. Its colour was a very pale brown. The different samples were submitted to the tests at the end of October 1859, and examinêd nine months afterwards, 4th August 1860. No. 1, placed in a net and exposed in the sun, open to air and rain, had become rotten, but it was neither viscous nor pulverulent. Its weight had increased 2·23 grammes, say 7 per cent. No. 2, exposed to air and light, but kept dry in a flask turned upside down, had increased 2·8 per cent. in weight in consequence of the absorption of oxygen, and had become brown, soft, and viscous, especially in the parts most exposed to the light. It yielded to alcohol 11·81 per cent. of a soft, viscous, oxidised resin. No. 3, exposed to diffused daylight, in open flask, filled with soft water, had become white and opaque by absorption of water, and increased 17 per cent. in weight, but it had undergone no alteration in its chemical properties; dried, it regained its original properties. No. 4, exposed to diffused daylight, in open flask, filled with sea water, had absorbed 3·6 of its weight of water, and its chemical composition was not altered. (*B.*) *Sheet of rolled Para.*—A similar series

of experiments were performed on a sheet of rolled rubber. No. 1, exposed to sun and rain, had segregated into a tacky mass, and lost tenacity and elasticity. No. 2, exposed in an inverted flask to air and diffused daylight, had increased in weight 0·52, say 1·6 per cent. It formed a small viscous mass, and had lost its elasticity, more especially in portions most exposed to action of light. Treated with alcohol, it gave up to that solvent 12·64 per cent. of its weight of a resinous body. No. 3, the changes presented a marked contrast with preceding observations in No. 3 of first series, which had been preserved in a glass flask kept in darkness, but open to air during same time. The sample had, in this case only, increased 0·6 per cent. It showed no signs of alteration so far as tenacity and elasticity were concerned, and only yielded 2 per cent. resin to alcohol. No. 4 consisted of a sheet of the same rubber which had been steeped in soft water in the open air and in diffused daylight. It had increased 87 per cent. in weight by the absorption of water, *i.e.* its weight had almost doubled. It had become white, opaque, pitchy and tacky to the touch, and on pressure allowed the water which it had imbibed to escape. Exposed to the air, it quickly lost the weight which it had gained. No. 5, similar to the preceding, but immersed in sea water; it was slightly tacky and opaque, but had only increased 5 per cent. in weight by absorption of the liquid. A second sample, placed in a flask filled with sea water, gave off a smell of sulphuretted hydrogen, and gained 5·6 per cent. in weight. It had neither lost in elasticity nor in tenacity. Latimer Clark's experiments show that if air and light combined have a baneful action on rubber, this action is worse in the case of the rubber which had undergone a mechanical transformation, and that the natural rubber is more resistant. They show, moreover, that immersion in water, and particularly sea water, is a preventative against this alteration. It is the duty of those actually engaged in the industry to profit by these remarkable properties.

Action of reagents.—1. *Acids (dilute) and caustic alkalies.*—These act but little on indiarubber.

2. *Hydrochloric acid (concentrated)*—both liquid and gaseous—attacks rubber. The change it undergoes is but little known.

3. *Nitric acid (concentrated)* attacks it feebly in the cold, energetically in the hot; colouring it yellow at first instance, it transforms it eventually into a greasy-looking body with disengagement of nitrogen, and finally into carbonic acid and oxalic acid. By prolonged ebullition, the greasy-looking substance is resolved into campho-resinic acid. Nitrous vapours act very violently and rapidly decompose it.

4. *Sulphuric acid (concentrated)* acts upon rubber as it does upon cork, and clears the surface even in the cold. The hot acid decomposes rubber very rapidly, with disengagement of sulphurous acid and carbonic acid.

A mixture of *sulphuric* and *nitric* acid attacks rubber very energetically.

5. *Hydrofluoric acid*, like the organic acids, has no action on rubber.

6. *Halogens—Chlorine.*—Gaseous chlorine exerts a very energetic action on rubber, deprives it of its elasticity, and finally renders it hard and brittle. Hartzig took advantage of this property to make some experiments in vulcanisation by chlorine.

7. *Iodine and bromine* exert an analogous action to that of sulphur. The reasons why the former acts more energetically than the latter are given in the special chapter on vulcanisation.

8. *Sulphur.*—The same remark applies to sulphur. Its action—as well as that of the alkaline sulphides, the sulphides of the alkaline earth, the metallic sulphides, and chloride of sulphur—is of great practical importance. If in some way or other indiarubber be mixed with these substances, and the mixture heated, the sulphur is more or less absorbed. According to the quantity of sulphur absorbed, and the amount of caloric which has intervened, the rubber becomes transformed into a more or less hard and elastic substance, which successively assumes the names of *vulcanised rubber*, *hardened rubber*, *ebonite*, etc. These transformations, of great importance industrially, form the subject of a special chapter.

9. *Alkalies*, even if caustic, only act feebly on rubber. This is not quite

the case if the mixture be heated, after a previous more or less prolonged digestion. The substance then softens, becomes tacky, and then dissolves in small quantity, according to Muspratt. Ure, on the contrary, asserts that caustic potash, even in very concentrated solution, leaves the substance intact. But experience teaches that if rubber be heated in a sealed tube to 100° C. (212° F.) for forty-eight hours with ten times its volume of liquid ammonia, the mixture is transformed into a kind of soapy emulsion having almost all the properties of the latex. This solution leaves the rubber on evaporation in an almost chemically pure state, but it retains a slight alkaline reaction, which it is difficult to free it from entirely. Ammonia may be regarded as a preservative; immersed in dilute ammonia (1 to 2) rubber goods become slightly more pliant.

Here terminates the summary study of the physical and chemical properties of natural rubber. Following the logical sequence, this should be the place to treat of the chemical transformations which rubber undergoes under the action of sulphur and its compounds, and of chlorine, bromine, and iodine. But for the better understanding of our subject it is necessary, before commencing this study, to know the mechanical transformation which natural rubber has to undergo before the manufacturer can use it for a special purpose. Before starting on the vulcanisation of indiarubber, it is, in fact, necessary to dwell on the different operations by which raw rubber is purified and normal rubber prepared.

Translator's Note.—The history of isoprene is interesting, as it is the supposed source of synthetic rubber. Berthelot was the first to express the belief that the terpenes might owe their existence to the more or less advanced state of polymerisation of a radical with the formula C_5H_8, and to his hypothetical pentene he gave the name of terene, the terpenes $C_{10}H_{16}$ being the diterenes and the products of more advanced condensation, the treterenes. The soundness of this theory has been proved by the examination of a carbide possessing this formula, which is formed, as we have just seen, in the destructive distillation which indiarubber or spirits of turpentine undergoes when exposed to a red heat. Long ago it was observed that volatile and liquid hydrocarbides were produced by the action of heat upon indiarubber. This is a phenomenon of retrogression accomplished by the destructive force of heat, which reduces the polymerised terpenes $(C_5H_8)^n$ into the formula of the simple hydrocarbide C_5H_8. Greville Williams' and Bouchardat's researches have already been described, and need not be further adverted to, but perhaps the most salient feature in the history of the pentene C_5H_8 is its decided transformation into dipentene $(C_5H_8)^2$. (As already mentioned, Himly had observed in the products of the destructive distillation of caoutchouc a compound boiling at 171° C., having the formula $C_{10}H_{16}$, which he called caoutchine.) This condensation is effected by simply heating isoprene to 280° to 290° C. in sealed tubes in an atmosphere of carbonic acid. Amongst other products a carbide is obtained boiling between 176° and 180° C., having at 0° C. a density of 0·866. It absorbs gaseous hydrochloric acid, yielding a monohydrochloride boiling at 145° C. under a pressure of 10 millimetres, and a solid dihydrochloride melting at 49·6° C. It therefore has all the properties of dipentene. Again, this identity of caoutchine with dipentene is confirmed by its transformation by Bouchardat and Lafont into inactive terpineol. They heated caoutchouc with gracial acetic acid to 100° C. for sixty hours. An acetate was thus formed which, saponified by alcoholic potash, produced a colourless, viscous, odourless substance, distilling in vacuo between 114° and 118° C., corresponding to the formula $C_{10}H_{18}O$ and crystals melting at about 25° C. capable of producing the crystalline form of a terpineol prepared from terpin hydrate. In spite of the too low melting-point, due to a trace of impurity, there is no doubt but that the body thus obtained is inactive terpineol.

Mokievsky has examined isoprene originating from the *destructive* distillation of spirits of turpentine. By combining it with hypochlorous acid he has separated two compounds responding to the formulæ of $C_5H_{11}ClO$ and $C_5H_{12}Cl_2O$. The first, boiling at 141° C., treated by potash, yielded trimethyl-ethylene oxide, which

was afterwards transformed into the corresponding glycol. The second compound, resulting from the combination of the carbide C_5H_8 with two molecules of acid, boils at 81° C. The isoprene in question therefore contains trimethyl-ethylene as well as pentene.

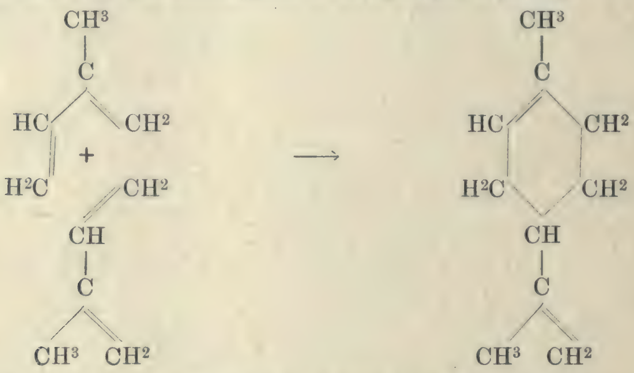
The constitution of isoprene has been reliably established by Wipatieff and Wœittf, who, working on isoprene boiling at 33° to 38° from the destructive distillation of indiarubber, treated it in the cold state by an excess of an acetic solution, hydrobromic acid. They thus obtained a mixture of the hydrobromides, which they fractionated under reduced pressure. The first runnings of small amount distilled under 74° C. under 16 millimetres. It consisted of tertiary amytic bromide from the trimethyl-ethylene. The main fraction distilled at 74° to 75° C. It consisted of β-dimethyl trimethyl-ethylene bromide.

$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!>\!CBr - CH^2 - CH^2Br$$

identical with that yielded by dimethylallene under similar circumstances. Isoprene has therefore got the following constitution :—

$$\begin{matrix} CH_2 \\ CH_2 \end{matrix}\!>\!C - CH = CH^2$$

This formula is confirmed by synthesis. β-dimethyl-trimethylene prepared from dimethylallene, treated with alcoholic potash, yielded a carbide boiling at 32° to 33° C., possessing the characteristic odour of isoprene, giving none of the reactions of the allenic or acetylenic carbides, and possessing in fact the formula C_5H_8. Treated by hypochlorous acid it yielded Mokievsky's fusible chlorhydrin. This formula, moreover, fits in well with the condensation of isoprene into dipentene.



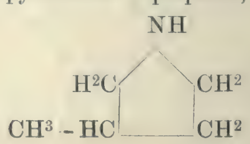
But this formula has been further confirmed by Euler's synthesis. Propylene bromide treated by potassium cyanide yields dicyanhydrin identical with the dinitrite of pyrotartaric acid.

$$\begin{matrix} CN - CH - CH^2 - CN \\ | \\ CH^3. \end{matrix}$$

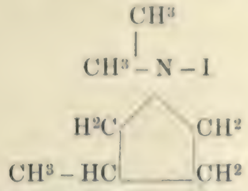
Reduced by sodium and alcohol this nitrite yields a base β-methyl-tetramethylene-diamine.

$$\begin{matrix} H_2N - CH^2 - CH - CH^2 - CH^2 - NH^2 \\ | \\ CH_3 \end{matrix}$$

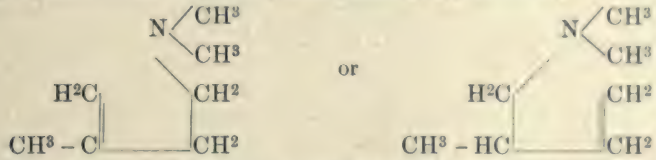
starting from which β-methyl-pyrrolidine is prepared,



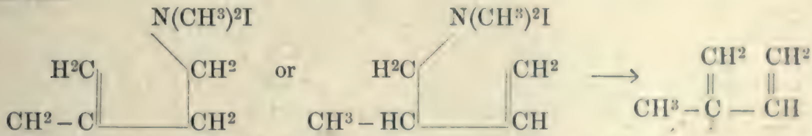
a base which treated by methylic iodide and potash yields the iodo-methylate of the methyl derivative—



The latter distilled over solid potash yields an oily base boiling at 112° to 115° C., having the constitution of dimethylated β-methyl-pyrrolidine,



This new base in its turn absorbs methylic iodide producing an iodo-methylate, which distilled with potash splits up in its turn into trimethylanine and a hydrocarbide.



This hydrocarbide boils at 33° to 39° C., is endowed with the smell and all the reactions of isoprene.

The following synthesis in the terpene series has been effected by Reboul, valeryllene or dimethylallene—

$$\left.\begin{matrix}CH^3\\CH^3\end{matrix}\right\rangle C=C=CH^2$$

is polymerised under the influence of sulphuric acid. Two products result from this polymerisation, the one answers to the formula $C_{10}H_{18}O$, and possesses, according to Reboul, a strong smell of peppermint and turpentine. The other has the formula of a sesqui-terpene $C_{15}H_{24}$ or $(C_5H_8)^3$. It boils between 265° and 275° C., and smells of turpentine.

CHAPTER VI

MECHANICAL TRANSFORMATION OF NATURAL RUBBER INTO WASHED OR NORMAL RUBBER (PURIFICATION)—SOFTENING, CUTTING, WASHING, DRYING, STORAGE.

Preliminary observations.—The raw material as it comes on the international markets, to be afterwards distributed amongst the industries which are to transform it into manufactured products, has alone been dealt with up to this point. But the high price which the article commanded from the very beginning of the rubber industry, together with the ignorance, apathy, and greed of the collectors, very soon led to fraud, and, in the humorous definition of Rousseau, "*the manufacture of indiarubber is the art of incorporating with it cheap substances without too far diminishing its particular properties.*" To be just, Rousseau might have added, "*and to improve it in certain cases*"; for there can be no doubt that sulphur or its compounds, far from being injurious, can only increase the value of indiarubber. If rubber came to market in a suitable degree of purity, the manufacturer could use it at once as it comes from the producing centres. It is very rare, however, that this is so, and, more especially wild rubber, some sorts of *Para prima* and plantation rubber excepted, rubber as imported always contain a more or less important quantity of foreign bodies, water, salts, earth, sand, vegetable débris, introduced into the goods, either during the collection of the latex, or during coagulation, or even during packing and transport. *Para prima* itself is not always exempt from such addition, whether fraudulent or not, and, some lots in bottles excepted, wild rubber must undergo a series of preliminary operations intended to purify it and free it from foreign matter. This purification process is commonly called the regeneration of the rubber. But as the rational cultivation of rubber extends in the tropics, accompanied by rational methods of treating the latex, the quality of the rubber put on the European markets must improve. At the present moment, however, it is vexing that preliminary purification should be necessary. Besides the considerable expense which it entails—the simple process *par excellence* being yet to be discovered—this preliminary work, more or less, deteriorates the quality of the substance, diminishes its resistance; in a word, it *unnerves* it. Purification is absolutely indispensable in any case, but more especially when the rubber is to be used in a state of solution. The history of purification is not a long one. Mechanical processes have nowadays superseded the early-day hand processes. The former cleanse more thoroughly; but the mechanical pulling about in every direction which the rubber suffers, far from improves its elastic and plastic qualities.

The storage of raw rubber—Site for store—Precautions.—Before discussing these four preliminary operations, it will be useful to mention what a well-equipped raw rubber store should be like. Generally, the manufacturer does not use up, all at once, the stock which he has received from the port of landing. He buys according to foreseen needs, but, as prices are liable to rise or fall, he makes his purchases at the right time. He must therefore store this stock, and the choice of a suitable site, so far as the preservation of a substance so liable to change as rubber is concerned, is important. The most appropriate warehouse is a rather dark, well ventilated cellar, so arranged that one lot is not heaped on the top of

another, or alongside, but widely separated either by wooden or masonry partitions. If one and the same lot be too bulky, it will not do to pile it up to too great a height. Two cubic metres of cakes or balls are the extreme limit to which a manufacturer should go in storing his stocks of rubber, with a constant division of say 10 inches between the lots. The floor of the warehouse ought, as far as possible, to be made of asphalt or cement. In concreting a floor on a level with the ground, it is sometimes useful, in case of flooding, to give it a slight rising longitudinal slope from one gable to another. These precautions are indispensable owing to behaviour of rubber during storage.

The cleansing processes as carried on nowadays are four in number—1. Softening, or superficial washing. 2. Slicing. 3. Washing. 4. Drying.

1. *Softening, or superficial washing.*—As it comes from the warehouse, the rubber undergoes the process of softening. It is then too firm and hard to be wrought, and at the ordinary temperature of our climate it is necessary to soften it whatever may be the form of the block. This, the most simple operation of all, consists in immersing the rubber in water, heated by a steam jet (a wooden vat is the best vessel), and keeping it in this bath for from twelve to twenty-four hours. With certain varieties it is advisable to add a little caustic soda to the water. Acidulated water is not to be recommended. The alkaline ley cleanses the surface better, especially any re-entering angles, and the woody fibre is better disintegrated. A sickening smell is given off from these vats, recalling the primitive methods of collection, especially in case of African rubber.

2. *Slicing.*—When the rubber is sufficiently soft, the large blocks are sliced. They are generally cut up into small coarse fragments of 3 to 5 cubic centimetres (say $1\frac{1}{4}$ to 2 cubic inches) in volume. Those kinds which come to the factory in very small lumps do not need to be cut up; they pass directly from the softening vat to the washer. The slicing is done, either by hand, by means of a big knife with a long blade drawn out to a point, or, mechanically, by means of a circular beater, as described by Heinzerling. This beater consists of an iron wheel of 30 centimetres (say 12 inches) in diameter and 20 centimetres (say 8 inches) in thickness, provided with several cutting blades, fixed obliquely, and going beyond the periphery some millimetres, and working as shown in figure. The wheel is driven by a belt, the cake of rubber is placed between the wheel and the palette, working in connection with a hinged lever attached to a pedal. When the workman places his foot on the pedal and adds to it by the weight of his body, the inferior rod lowers, and the lever, by means of the palette, pushes the rubber against the wheel. To stop the machine, the lever is drawn behind by the hand of the workman, who draws his foot off the pedal; the latter is provided with a counterpoise which facilitates this movement. The wheel revolves at great speed. In France, different machines, based on the mechanical action of a circular saw without teeth, but very sharp, are used. The blade of this saw dips into a small trough filled with water. It is thus kept continually moist and cool, to prevent adherence or heating, and enable it to get a cutting grip of the rubber.

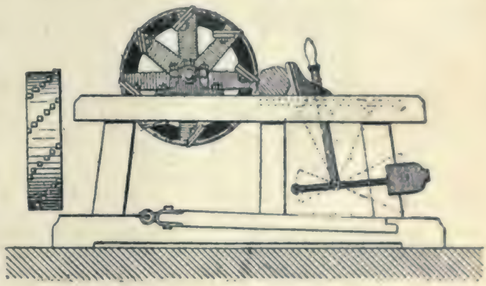


Fig. 39.—Machine for cutting up raw rubber.

3. *Washing.*—This operation, the essential part of the mechanical transformations which rubber undergoes during purification or regeneration, consists in passing the softened rubber, whether cut up or not, through very powerful machines capable of freeing it from foreign bodies imprisoned in its mass, which would be prejudicial to any further treatment. *The old process*, that of the mortar, is now obsolete. The German process, called the shredding

(*à raboter*) machine process, and the Dutch process, both are likewise obsolete. The British process, generally adopted, involves the use of the shredding or tearing machine (*déchiqueteur ou écraseur*). This machine consists of two rolls of hardened cast-iron, placed horizontally opposite each other; turning in opposite directions and with differential speed, only one of these is driven directly. It transmits its motion to the second by straight helicoidal or chevron gearing according to force required. Sometimes the rolls are fluted (covered with spiral hollows); sometimes they are smooth; sometimes one is smooth, the other striated or fluted: in any case the arrangement is the same.

British and American types of washing machines.—British and American factories prefer grooved or fluted rolls. The grooves in America are made especially of a spiral shape; whilst in Britain they more generally intersect in the form of lozenges. The asperities of the rolls thus facilitate the shredding; they penetrate into the rubber, and crush all the foreign bodies which it may contain. The two rolls (Fig. 40) rest upon two strong cast-iron supports by means of

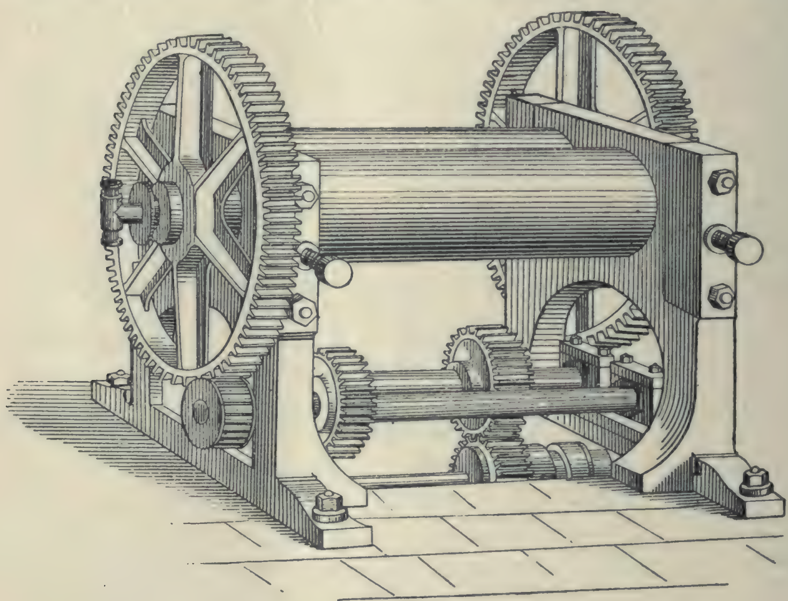


Fig. 40.—Washing machine.

stuffing-boxes fixed in the spaces left vacant for the purpose in the casting. The two stuffing-boxes of the roll at the back of the machine abut against the building; the two stuffing-boxes of the front roll are supported by two tightening screws. The two rolls are driven by gearing shown in the drawing; they revolve in opposite directions, and in the machine illustrated are driven by an intermediate shaft. Washing machines, as just stated, are also constructed of a different pattern, in which the revolving motion is directly transmitted from one roll to another.

Tightening and slackening the rolls.—The two rolls may be brought in contact by manipulating the tightening screws. To obtain the inverse motion, all that has to be done is to slacken the screw; the rubber fed into the machine whilst in motion pushes back the roll by the simple pressure which it exerts. Underneath the rolls is a wrought-iron collecting tank covered by a perforated plate. Water from a distributing pipe (Fig. 41) flows between the two rolls, and the wash water runs away through another pipe placed in the bottom of the tray. This water is spread automatically on the periphery of the rolls by a pump driven by the motor shaft, which aspirates it from the tank below the washer. This current of water

facilitates the "washing" of the rubber it dissolves, or removes certain impurities brought to the surface by the continuous renewing of that surface. To start washing or shredding, a very small quantity of rubber is introduced between the rolls whilst in motion, say 1 to 2 kilogrammes (say $2\frac{1}{5}$ to $4\frac{2}{5}$ lb.) at the most, according to the strength of the machine, and the water-tap is turned on. The distance is regulated to 3 to 5 centimetres, or from 1 to 2 inches. The rolls revolve in contact with

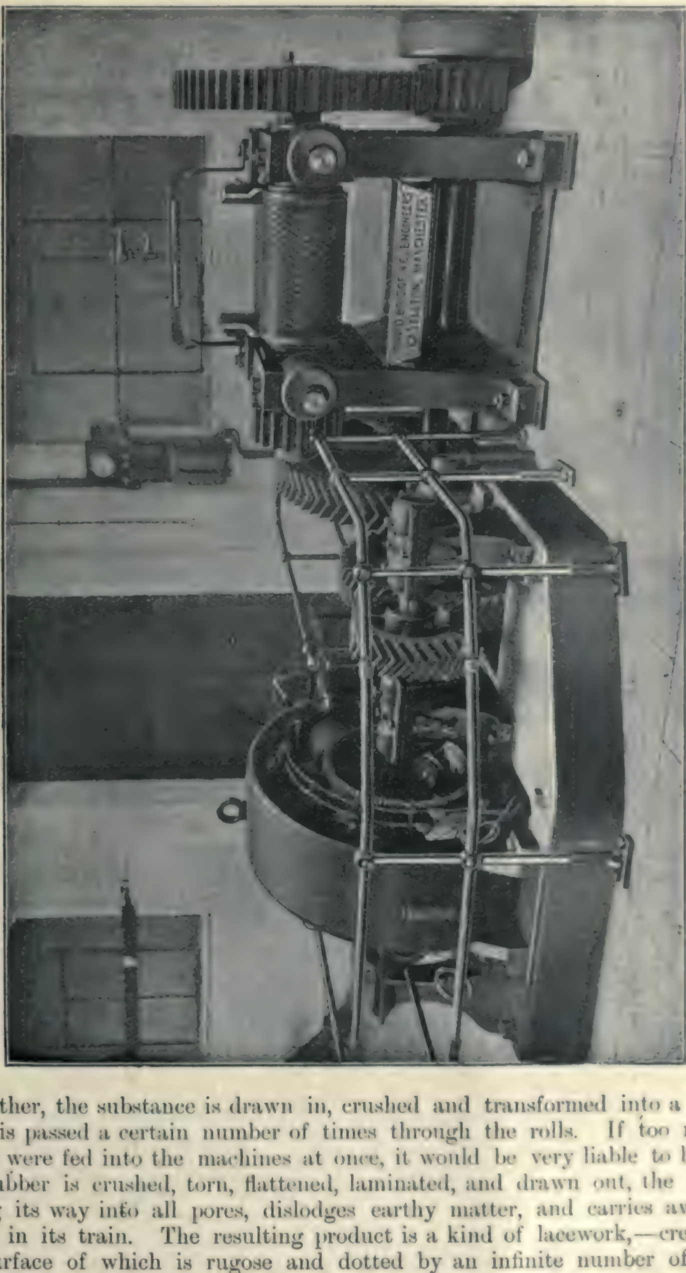


FIG. 41.—Indiarubber washing machine driven by electric motor.

each other, the substance is drawn in, crushed and transformed into a thin sheet, which is passed a certain number of times through the rolls. If too much sliced rubber were fed into the machines at once, it would be very liable to break them. The rubber is crushed, torn, flattened, laminated, and drawn out, the wash water finding its way into all pores, dislodges earthy matter, and carries away foreign bodies in its train. The resulting product is a kind of lacework,—crepe, felts,—the surface of which is rugose and dotted by an infinite number of asperities, separated by cavities which give to it a characteristic appearance.

Size, etc., of rolls.—Machines vary in size. Generally the rolls are 0·60 to 0·65 metre (say $23\frac{1}{2}$ to $25\frac{1}{2}$ inches) long and 0·40 to 0·45 metre (say $15\frac{3}{4}$ to $17\frac{3}{4}$ inches) in diameter; the revolving speed is then eight to twelve turns of the one to three to four turns of the other.

Hollow steam-heated rolls.—In certain factories the rolls, instead of being solid, are hollow, and so designed that, as occasion requires, a current of steam may be injected into them. They then serve two purposes. All varieties of rubber are not washed with the same ease. Para, as it contains but few impurities, is the most perfectly and most rapidly washed. Greasy, tacky rubbers are not easily freed from foreign bodies, and one is often obliged to give up the idea of eliminating the impurities which remain glued in the mass. Some Guayaquils are especially intractable. Very dry rubbers cannot be rolled into lacework, the fragments do not agglomerate together, and in certain cases they come out of the washing machine in the state of powder. After appropriate washing, the shredded

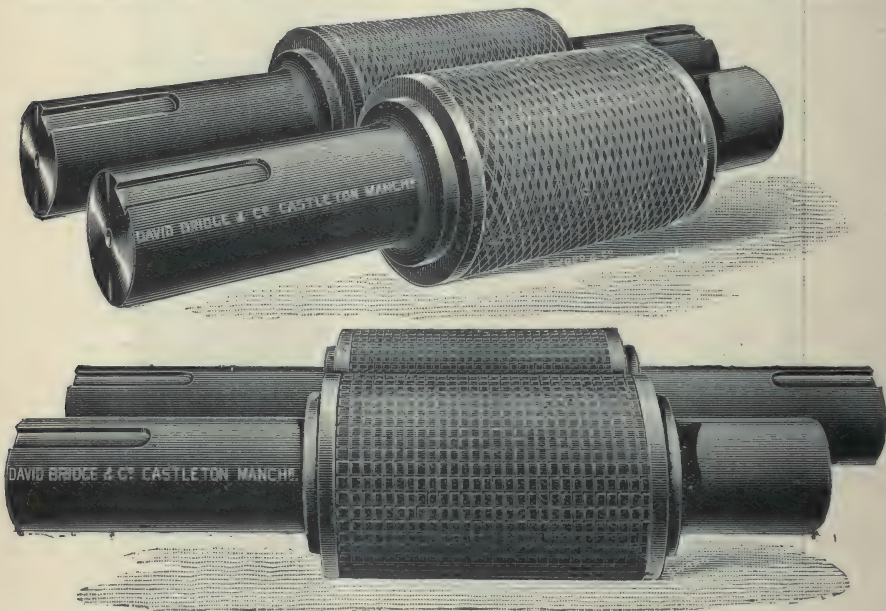


FIG. 42.—Rolls for washing machines.

lacework or sheet contains no foreign substance except water. Drying is thus the final stage of the "washing" process.

4. *Drying, aëration, and illumination of drying-room—Loss in washing.*—Washed rubber is dried by spreading the "skins" on stretched iron wires, or in stoves capable of being heated to 50° to 60° C. (122° to 140° F.). This simple operation requires no important remark. It may, however, be observed that "greasy," "tacky" rubbers require to be dried at a low temperature; by drying them at too great a heat their natural defects would be accentuated, the skins would be torn, would fall on the ground, and agglomerate into lumps, from which the moisture could only be evaporated very slowly and with great difficulty. Good, well regulated ventilation accelerates the operation, which in summer is finished in a few days. In winter, drying naturally takes longer, and steam drying, done with great care, assists in the work. In regard to light, there is a drawback to leaving the rubber exposed to this atmospheric agent. *The darker the drying-room is kept, the more valuable is the resultant dried rubber.* *Storing the washed rubber.*—When dry, the rubber is lifted off and formed into bundles by folding it like cloth, or, better still, by rolling it up on itself. The

rubber is stowed in bundles in a part of the warehouse used specially for this purpose, and protected from moisture and light, where it remains until required for industrial purposes. *Loss in weight in washing and drying of raw rubber.*—Washed and dried rubber loses in weight in the process. The difference between the weight of the raw rubber and the net weight in the dry state gives the *loss on washing*. This factor varies greatly, and, with inferior kinds, may rise as high as 60 per cent. of the initial weight; good sorts generally lose 15 to 20 per cent. The following table indicates the loss in the case of some rubbers. The figures are not at all given as constant or absolute. It is not rare to meet with two lots of the same rubber, sold as being of the same quality, which yield losses which may differ to the extent of 15 to 20 per cent. from the averages indicated.

TABLE XXXII.—SHOWING LOSS ON WASHING EACH COMMERCIAL BRAND OF CRUDE RUBBER.

Kind of Rubber.	Loss per cent.	Kind of Rubber.	Loss per cent.
Para	10 to 16	Guatemala . .	20 to 40
Sernamby	15 to 35	Assam . . .	10 to 30
Mozambique (spindles) .	15 to 25	Java . . .	20 to 35
Mozambique (rose-red balls)	15 to 25	Borneo . .	10 to 45
Colombia	10 to 25	Guayaquil . .	30 to 50
Peru (sheets) . . .	30 to 40	Senegal, Soudan .	20 to 35

Good dried washed rubber contains about 0·5 to 3 per cent. of impurities. Although trade exigencies lead to the use in factories of imperfectly dried rubber, it would be highly desirable, from a manufacturing point of view, only to use an absolutely dry substance.

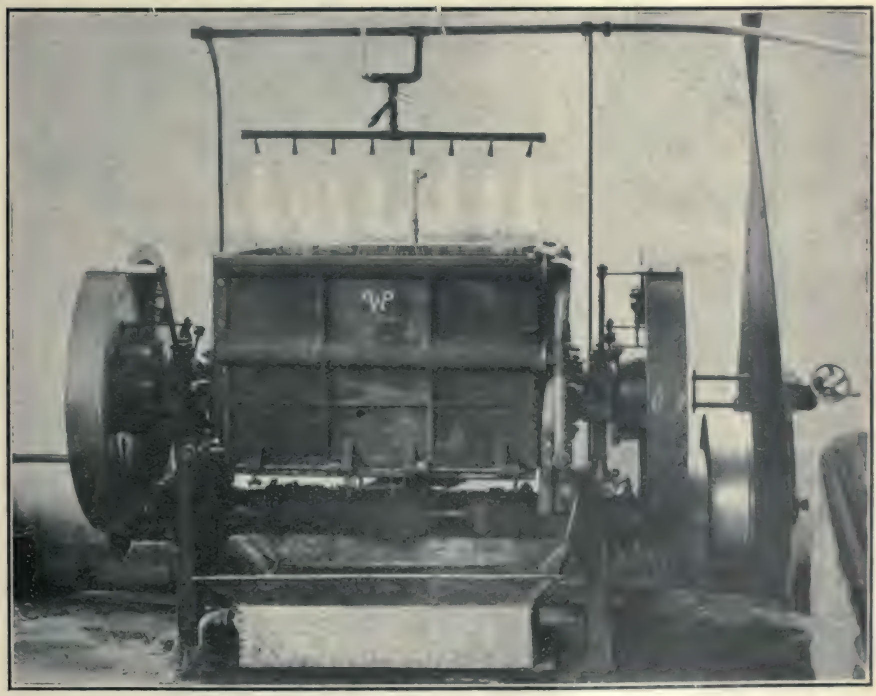


FIG. 43.—Washer for indiarubber (Werner Pfleiderer).

CHAPTER VII

MECHANICAL TRANSFORMATION OF NORMAL RUBBER INTO MASTICATED RUBBER

Definition of mastication.—As it comes from the washer, the dried rubber is ready to be treated with solvents. But unless it is to be used industrially, in the state of solution, washed rubber has no direct application: it is simply a stage through which the substance passes before being transformed into manufactured products. What the washing machine has dissociated, the masticator or kneader has to reunite: the normal rubber is thus freed from the air and moisture which it contains in its pores, and a more dense and more homogeneous product is

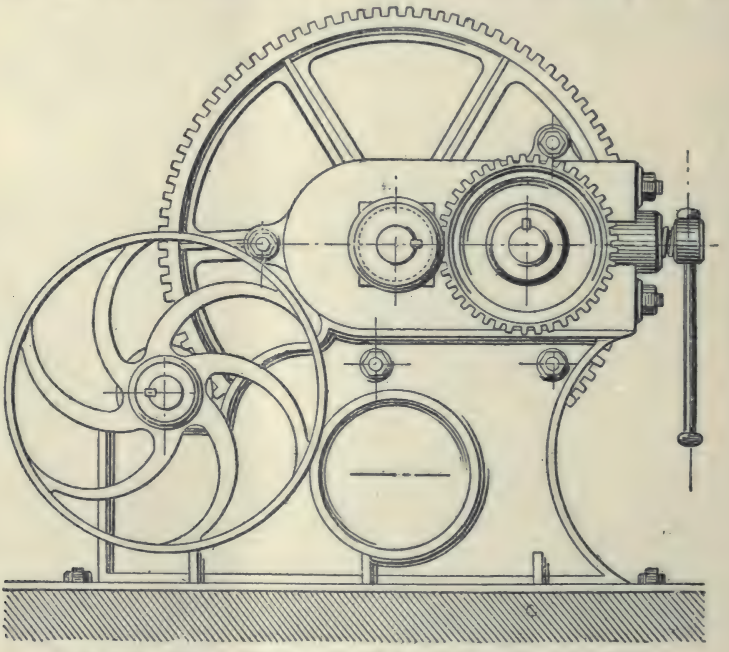


FIG. 44.—Mixer—Horizontal rolls in juxtaposition (elevation).

obtained. This result is realised by forcing the different portions together, mechanically, so as to agglomerate them together into one single whole.

Agglomeration, mastication, or kneading.—As in the "washing" process, obsolete superannuated processes, forsaken by actual practice on the larger scale, have not been described. The old kneading process of Thomas Hancock need only be mentioned. It is unnecessary to describe the construction of the *wolf* or *devil*, even when furnished with all the improvements so ingeniously brought to bear upon it by Auber and Gerard. The "deviling" of indiarubber requires much time, and gives rise to an elevation of temperature prejudicial to its quality; it requires

a considerable expenditure of force, which for the kneading of 10 to 15 kilogrammes (say 22 to 33 lb.) is not less than 5-horse power (nominal). Moreover, the process is becoming more and more obsolete, and factories equipped after a more recent system have advantageously replaced it by a mixer with grooved rolls. The masticator is comparatively easily driven, the operation is much more easily watched, and the heating of the rubber is avoided as well as all the inconveniences incidental thereto. There are two kinds of masticators: the masticators with parallel horizontal rolls in juxtaposition, and the masticators with superimposed rolls. The latter are not used so much in France. Figs. 44 and 45 show a masticator with rolls in juxtaposition, in a horizontal sense. It is the American washing machine invented by Goodyear, with this difference, however, that the cylinders move at the same speed, the rolls are always hollow, and can therefore be heated by steam.

Figs. 46 and 47 represent a machine with superimposed rolls.

Description.—*a a* are the hollow rolls; the lower one moves in the frame *b b*,

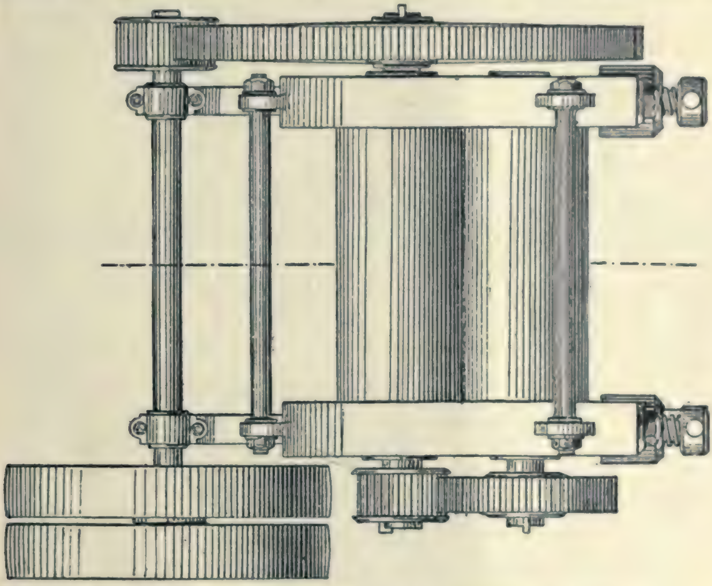


Fig. 45.—Mixer—Horizontal rolls in juxtaposition (plan).

whilst the upper roll is so arranged that it may be brought near to or withdrawn from the lower roll by a lever and counterpoise. The weights *c* lower (by the lever *d*, and the rod *e*), the levers *f*, which, controlled by the rods *g*, press upon the supports of the upper roll, and cause it forcibly to approach the lower roll. The upper roll thus yields to an abnormal force, such as would be caused by stones in the rubber. Damage to one roll or the other if both were fixed is thus avoided. To regulate the machine the extremities of the levers *d* are furnished with chains *h h*, winding on shafts *i i*, and are tightened by *k*, wrought by the lever *l*. The rolls are heated by the steam pipe *m*; the excess of steam and the condensed water are evacuated by blow-off cocks *n n*. The steam pipe is regulated by a screw valve. The dimensions of the rolls are generally 1·3 metre (say 4 feet 3 inches) long by 0·45 to 0·50 metre (say 17$\frac{5}{8}$ to 19$\frac{5}{8}$ inches) in diameter.

Recent forms of masticators.—In certain recent forms of masticators the levers and counterpoises are replaced by spring compressors (which can be compressed at will), fixed in the stuffing-box of the upper roll. They serve the same purpose as the old system; they hinder the rolls from being damaged by the interposition of a hard resistant body. The surface of one of the rolls is smooth

and uniform, whilst the other bears all over its circumference and parallel with its axis deep grooves of about 15 millimetres deep and 30 millimetres wide (0·59 by

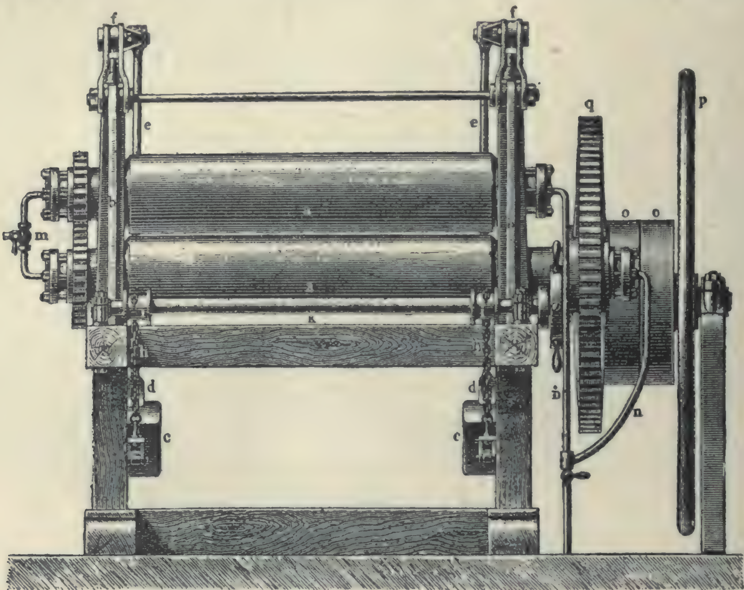


FIG. 46.—Mixer, with superimposed rolls (elevation).

1·18 inch). The angles which these grooves make with the surface of their roll are not equa', but alternately obtuse and acute. The acute angle comes first in the

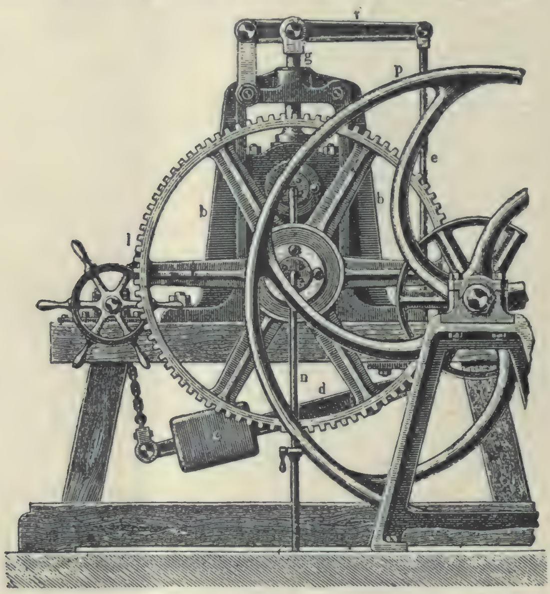


FIG. 47.—Mixer, with superimposed rolls (side view).

contact with the smooth roll during the working of the machine. These rolls revolve at unequal speeds, the grooved roll making two revolutions to every one of the smooth roll. When the laceworks of rubber from the washing machine are

masticated, the rolls are first heated, then as much of the substance as it can take is gradually fed into the machine, that is, 11 to 22 lb. for rolls of the above dimensions. The machine when charged is started, and as soon as it works it is gradually tightened, so as only to leave a space of a few millimetres between the rolls. The rubber is thus constantly forced to enter the grooves which come successively in front of the surface of the smooth roll, and it is energetically drawn in by the acute angle of the groove which catches there. The result is continued

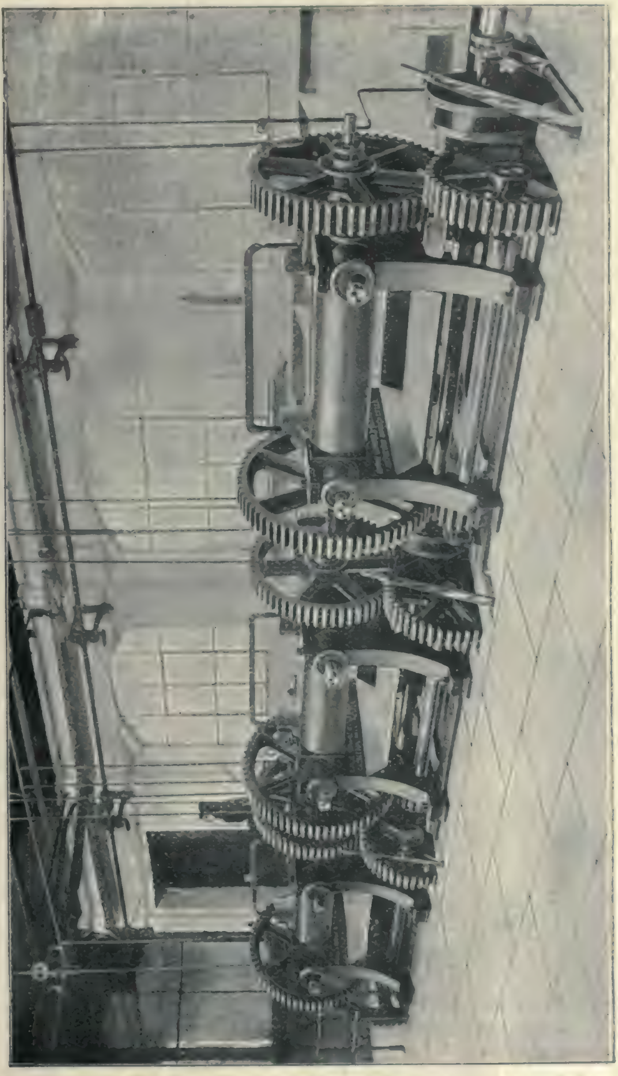


FIG. 48.—Improved mixing machine driven by electric motor and fitted with patent friction clutch (the rollers are hollow for steam heating and water cooling).

and repeated mastication, which soon renders the mass of rubber very homogeneous. The rolls generally revolve with a speed of twenty revolutions a minute. The substance, once masticated, is again passed between the rolls, and the treatment repeated as many times as necessary.

Necessity for care in mastication—Special mastication of African rubbers.—The mastication of rubber is a most important operation, and requires great care to avoid grave defects in the rubber. If the rubber be but imperfectly dried, a

mastication of forty to forty-five minutes is required to eliminate, by evaporation, the excess of water present. In many factories rubbers from different sources are masticated separately. To the African sorts, which tend to become tacky under the action of the hot rolls, a little talc (hydrous silicate of magnesia) is added, and the steam is carefully regulated. Moreover, they require to be masticated for a much longer time than good sorts, and particularly much longer than Para.

Incorporation of sulphur and colouring principle.—After mastication, before being blocked, the indiarubber may be "mixed" by the same rolls as are used for mastication. "Mixing" is the introduction into the rubber of the sulphur, or the solid derivatives thereof required for vulcanisation, and, if need be, of different mineral or tinctorial substances necessary for each special use to which the rubber is to be put. *Vulcanisation* can only be proceeded with after that has been done.

Blocking—Passing between the hot rolls.—The sheets or bundles of rubber as they come from the masticator are very irregular. It is impossible to utilise them in that state. They do not possess the desired texture: certain portions are more nervous than others, and sheets made from them would swell and become useless. The rubber must therefore be subjected to a fresh process, especially if it be desired to make cut sheet and English sheet. This operation is called blocking. The masticated rubber is converted into regular shaped plates by being passed between two hot rolls—at a temperature of 80° C. (176° F.)—the space between which varies between 3 and 40 millimetres (0·1179 and 1·5720 inch). Fairly equal sheets are so obtained.

Hydraulic pressure of the rubber in frames after passing through hot rolls.—A certain number of sheets imparted are made into one, whilst the heat during rolling still causes them to be adhesive, and they are put into a cast-iron frame of 25 to 30 centimetres wide (say 10 to 12 inches) and 2 metres long (say 6½ feet). They are pressed very forcibly with a hydraulic press, and let cool under pressure.

Storage of blocked rubber—Changes produced.—After a few days the rubber sheets are taken from the frames and piled in a cool cellar, where they lie for several months. During this prolonged storage a change supervenes in the soft matter, which is present in greater or less abundance in each parcel of rubber in admixture with the more nervous portions. The degree of hardness is equalised, and the mass becomes thoroughly homogeneous. It is then cut into thin sheets. No marbling nor striæ due to the greater or less nerve of the mixture of rubbers forming the block can any longer be perceived. By prolonged treatment with masticating rolls, the whole mass may be made still more homogeneous, but this treatment would inevitably result in heating and prejudicially unnerving the rubber intended to be used in the normal condition. The rubber thus blocked, and stored in the cellar during several months, naturally assumes the form of the mould employed. Cubical parallelopipedical blocks are made of the size indicated, and cylindrical blocks of 0·3 to 0·4 metre (12 to 15¾ inches) in diameter and 0·4 metre (15¾ inches) in height. It is used in the making of sheets or discs, from which ribbons are cut by a mechanical knife for making block-rubber thread, but this manufacture is now almost entirely abandoned.

English sheet.—The great use of blocked rubber consists in the manufacture of *cut sheet* and English sheet. The rubber which has been stored sufficiently long in the cellars is used for this purpose. It is thawed gently in the stove, then it is made to stick with a solution made from spirits of turpentine, and more especially benzol, on the car of a saw, in which the blade of the saw has been replaced by a blade without very sharp teeth; a jet of weak soapy water continually moistens the blade to prevent it from heating and adhering to the rubber. To obtain sheets of double width, two blocks, by means of a little of the previously mentioned solution, are soldered together by their extremities, which have been cut exactly at a right angle. The cutting is done just as in the case of a single block; it only requires a car of double the length. In another system the cubical block is fixed on a sliding plate like the plate of a planing machine. The plate is brought mechanically to the front, whilst the knife, propelled by a to-and-fro movement at

the rate of 1500 to 2000 cuts a minute, slices off a thin sheet of rubber. The parts of the machine are brought back to their original position, the block-carrier plate is loaded with a quantity corresponding to the thickness desired, and so on until the whole has been used up.

Guibal's sheet or continuous cut sheet.—The cutting of cylindrical blocks

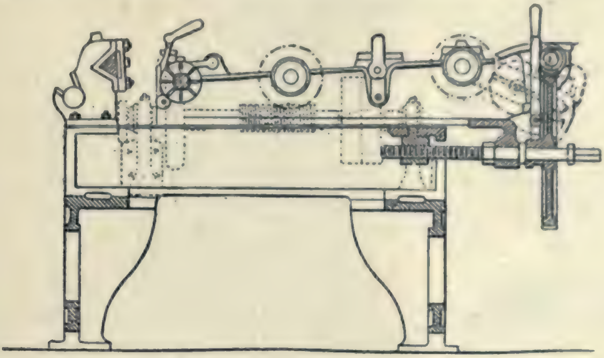


Fig. 49.—Machine for cutting a continuous sheet of rubber. Leblanc system (elevation).

producing so-called continous cut sheet differs. This system, invented by Guibal, consists in taking a cylindrical block and imparting to it a rotary motion round its own axis, whilst a knife blade constantly moistened by a jet of water cuts it spirally. The length of the sheet thus produced varies with the thickness; it

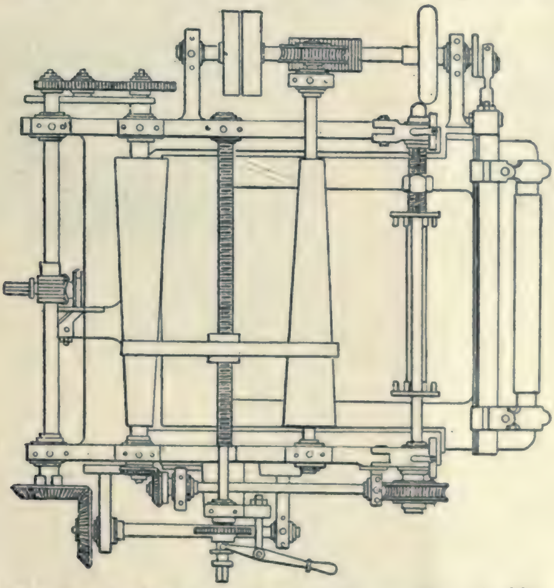


Fig. 50.—Machine for cutting a continuous sheet of rubber. Leblanc system (plan).

sometimes attains a length of 500 metres (1640 feet). Figs. 49 and 50 represent the elevation and plan of Guibal's machine as made and improved by Leblanc.

Features of the Guibal-Leblanc machine.—As the cylindrical block diminishes, the speed of rotation increases, so that the surface in contact with the knife preserves a uniform speed during the whole of the operation. This arrangement is intended to produce sheets, the rays of which, marked by the knife, are perfectly

equidistant. Leblanc's machine produces thinner sheets than hitherto. They can be made as thin as 0·18 millimetre, whilst a little more than ten years ago 0·30 millimetre was the thinnest that could be made.

Fig. 51.—Schopper's "Automatic" thickness gauge.

It was formerly held that to obtain a perfect cut sheet very good Para rubber must be used, and the blocks cut at a very low temperature. The second part of this assertion may be well founded. But as to the first, the recent researches and analyses of Henriques show that such is not at all the case.

Cut sheet is not treated with talc, but gently rubbed with a very clear solution of soap in hot water. This solution on cooling coagulates, forming a very thin layer on the surface of the sheets, which hinders them from adhering together.

Apparatus for ascertaining thickness of india-rubber sheets.—This apparatus (Fig. 51) registers automatically with mathematical precision the thickness of every description of rubber, caoutchouc, web fabrics, felt, paper, cardboard, etc. The machines can be supplied graduated in inches.

Fig. 52.—This is made of German silver and provided with a sensitive screw and large measuring drum. Fastened by two springs on a round base, the apparatus is easily detached. Graduation: 0 to 10 millimetres; divisions into $\frac{1}{100}$; (*a*) with visible screw, (*b*) with masked screw.

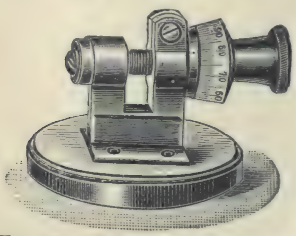


Fig. 52.—Micrometer for rubber (Schopper, Leipzig).

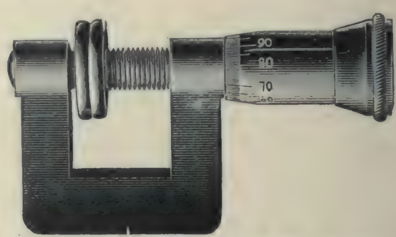


Fig. 53.—Micrometer for rubber, etc. (Schopper, Leipzig).

Fig. 53.—Made of German silver and provided with a sensitive screw. Graduation: 0 to 10 millimetres; divisions in $\frac{1}{100}$; (*a*) with visible screw, (*b*) with masked screw.

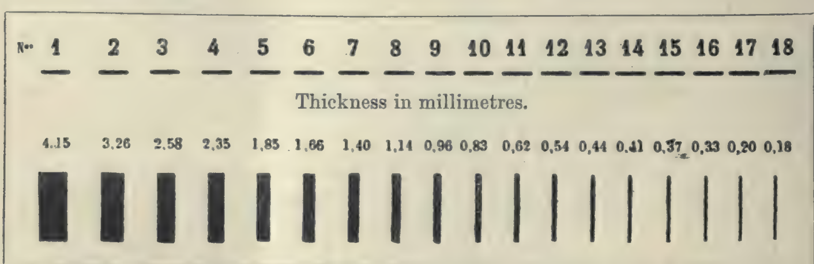


Fig. 54.—Diagram of the different thicknesses of English sheet rubber.

Use and application of sheet rubber.—These sheets are used in the manufacture of a number of small articles—tubes, bracelets, rings, balls, pears for surgical appliances, air cushions. *Method of manufacturing sheet rubber into commercial*

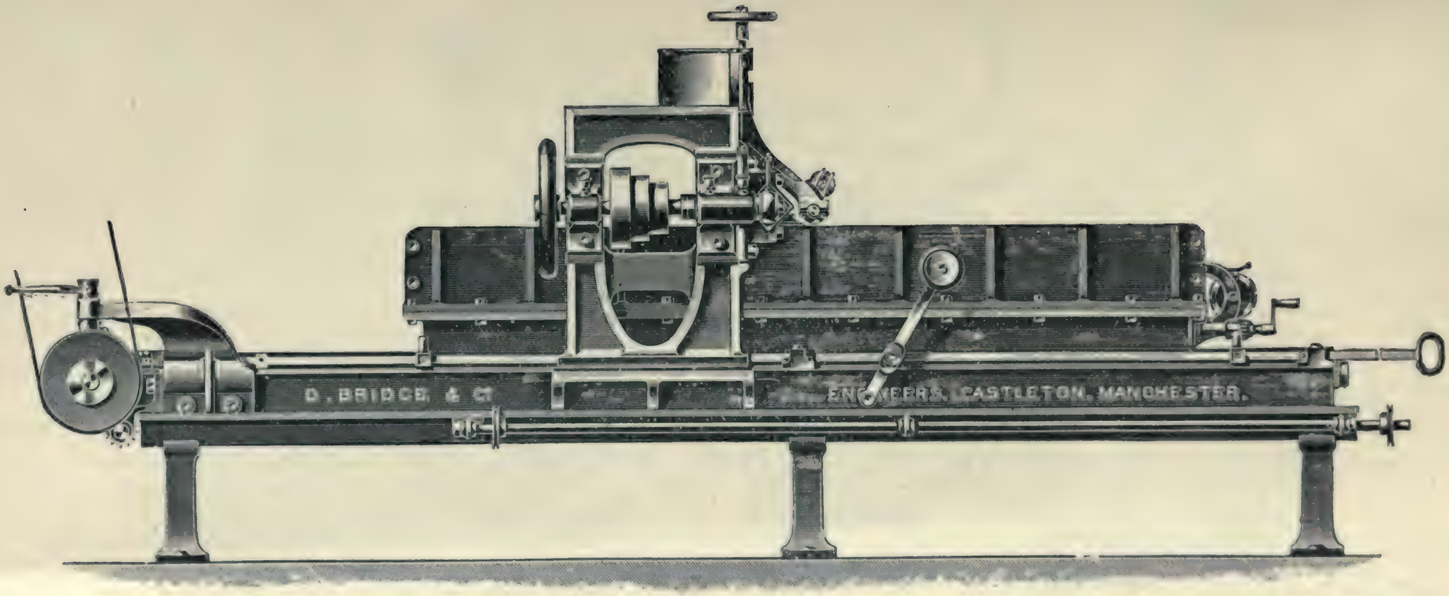


FIG. 55.—Bridge's improved horizontal sheet cutting machine specially designed for cutting fine sheets of purest Para rubber from blocks first made by hydraulic pressure, in suitable moulds, and capable of cutting up to 120 sheets per inch, in thickness, consists of box 9 feet long, 22 inches wide, with movable bottom, lifted at every cut by a suitable worm-wheel and screw, operated by handle, at one end, with index. This box is caused to slide backwards and forwards, on its cast-iron bed by a screw, worked by bevel gear at one end, with quick return motion and fast and loose pulleys. To prevent water splashes, the bed is fixed inside cast-iron tray, supported by standards, and a shaft with rope pulley secured to same, to run the table or take bottom of box down by power if desired. An automatic, adjustable stop prevents box travelling too far. The knife or cutter is fixed on an improved holder to which a slight motion is given by excentric, worked at a considerable speed from a shaft driven by three-speed cone pulley, and fitted with balanced fly-wheel, the whole being firmly supported by a strong fixing on bed of machine. A pressing roll, supported by bracket, in adjustable vertical slide, is laid in front of knife, and a small batching roll is driven off same by contact. A water drip can is fixed on bracket, supporting knife, so that a stream of water meets the cutting edge of same to facilitate cutting.

articles.—It is very easy to make these different objects: the two edges are cut a little obliquely and the two sections brought together with a little pressure; they join immediately, if care be taken to run over those portions with a brush which has been slightly dipped into benzol, which is left to evaporate before uniting them. Afterwards the point where the junction has been made is struck with a small round-ended hammer, and the joint is as solid as if the sheet had not been cut. It is necessary, if the sheet has been "frozen," to "thaw" it either on the steam table or in a stove before starting to the work. It is only then that it regains all its adhesive properties. Cut sheet is not made solely from pure rubber. It is also made from rubber in admixture with other substances; in such cases the powders or colouring materials are mixed with the rubber in masticators with special rolls, and the mixture so obtained is treated like pure rubber, that is to say, blocked,

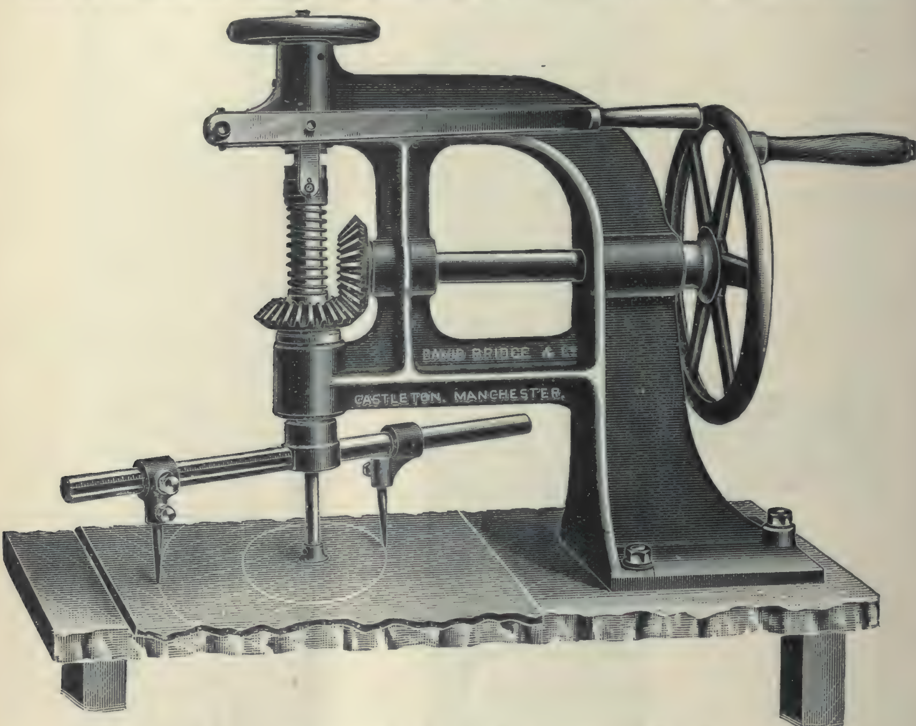


FIG. 56.—Machine for cutting circular sheets or "washers."

frozen, and then cut. Before being put on the market, all articles manufactured from English sheet have to be vulcanised by special processes.

Mixers or crushers—Rolls—Guide plates—Collecting tank—Shafting.—The mixer (Fig. 57) consists essentially of two horizontal cast-iron rolls placed alongside each other, turning in opposite directions and at different speeds. The two rolls, 20-inch diameter, are hollow with smooth surfaces; they rest on cast-iron foundations by horizontal bearings fixed in the spaces left vacant for the purpose. The two bearings which support the front roll are acted on and brought near to the other roll by two strong tightening screws, visible on the front part of the machines, the bearings of which abut against the framework. The inverse movement takes place of its own accord by undoing the screw, for the substance introduced between the two cylinders presses against the mobile roll and pushes it back. Suitable guides placed between the rolls prevent the substances from coming out or slipping on to the bearings or shaft on which the rolls turn. Underneath there is placed a sheet-iron collecting tank (not shown), intended to receive the material as it

comes out of the machine, which is driven by gearing. In many of these machines the rotary motion is not transmitted direct from the one roll to the other, as shown here, but by an intermediate shaft.

Hot and cold rolls.—The two rolls are hollow, and may be heated or cooled at

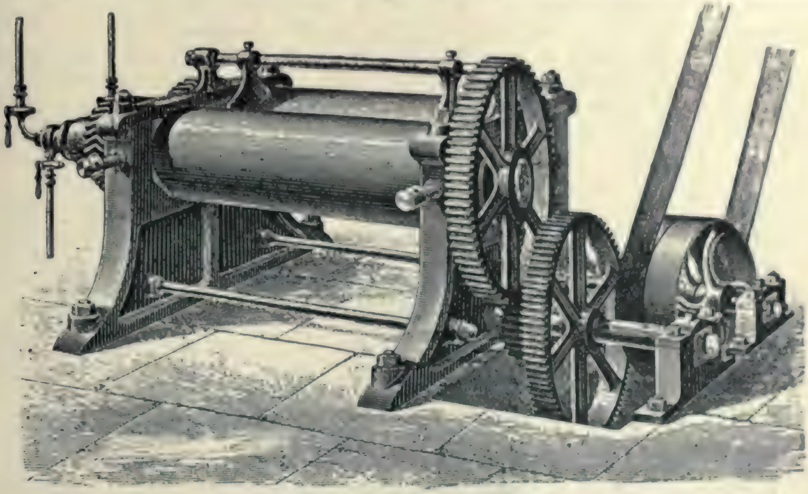


FIG. 57.—Rickkers' crushing mixer.

will. A pipe runs along the outside of each roll to the opposite end from whence it entered, communicating (1) with a supply of cold water, and (2) with the steam boiler, so that, by opening one or other of the taps which regulate these conduits, either steam or cold water is shot into the roll. The condensed water is run off

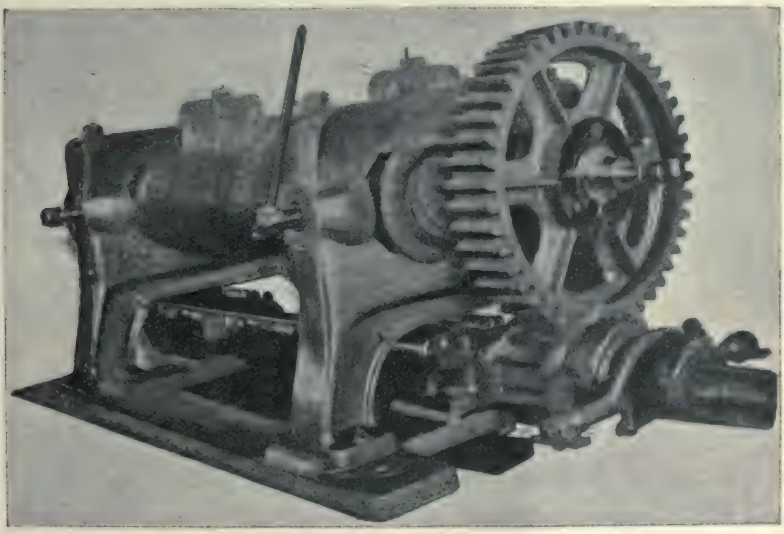


FIG. 58.—Large calibre mixer of the Birmingham Iron Foundry (Connecticut).

through a blow-off cock. The pipe system passes through a layer of tow pressed against it by suitable means. The working of the rubber between the rolls develops a considerable amount of friction, and, as the cylinders become gradually more and more heated, an injection of cold water is required to bring them to the

desired temperature. There are certain kinds of work, namely, crushing indiarubber waste, which can only be done quite cold. If the admixture of substances added to the rubber be soft, it causes the block to be wrought to become more and more plastic, and consequently sticky. If the mixture were not at a suitable temperature the paste would adhere to the rolls, and would render work impossible. The treatment to which the mixers subject the rubber is not a laminating process, as might at first sight be supposed: it is a spreading out and a crushing process, produced by the roll revolving with the greatest velocity on the mass retained in part by the roll revolving with the slower speed. It is a work of the same kind as that of the muller on the marble slab, where the painter "rubs up" the mixture of oil and powdered pigment. Mixing is effected by introducing the masticated rubber between the two heated rolls of the mixer. When it has acquired a suitable degree

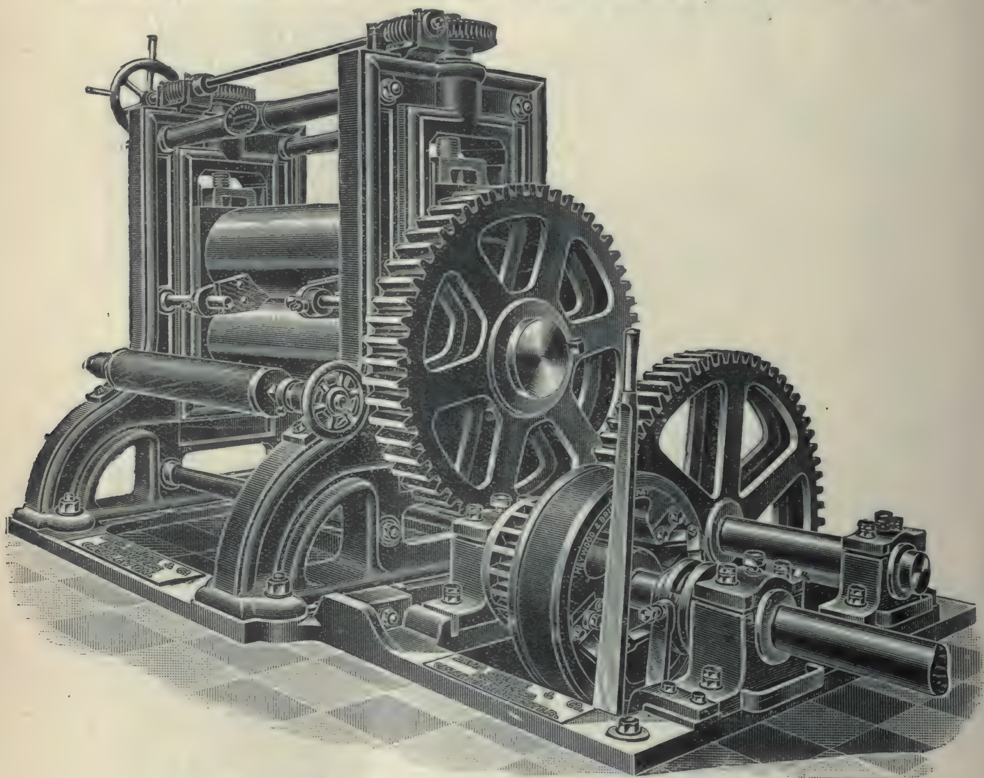


Fig. 59.—Heavy two-roll calender driven by patent friction clutch.

of malleability, the powders to be used in the mixture are gradually spread over the surface of the sheet of rubber around the far roll. A large proportion of the powders fall into the collecting tray, and are picked up by a shovel and brush and passed between the rolls again until the whole is well incorporated with the rubber. The pasty mass is passed through the mixer until it has become quite homogeneous. Finally, the two rolls are tightened up, and it is again passed through once or twice so as to crush any particles well which might escape the action of the machine. The substance issues as a thin sheet, which is rolled upon itself into a large block for subsequent operations. All these mixed rubbers, whatever may be the nature of the materials incorporated, are passed through the crushing mixer.

Automatic mixer.—This machine, described by Bobet, is intended to lift up automatically the substances which fall into the collecting tray of the ordinary crusher. Moreover, it does not differ from the machine just described, except by

the addition of an endless apron of strong canvas, turning underneath the rolls in the place usually occupied by the collecting tray. This apron conveys the substances it collects above the rolls and tilts them uniformly between the two. This arrangement ensures constant and regular feeding and a homogeneous mixture; besides, the operation is accelerated since all the mixing surface is utilised. With the ordinary machine, when the substances which have fallen into the collecting tray are picked up with a shovel and a brush, their re-spreading out is irregular, and certain portions of the sheet of rubber do not get anything. Theoretically, therefore, this machine presents some advantages, but its use does not appear to have been consecrated by time and practice.

Rolled (laminated) or drawn-out sheets—Calendering.—Instead of cutting the

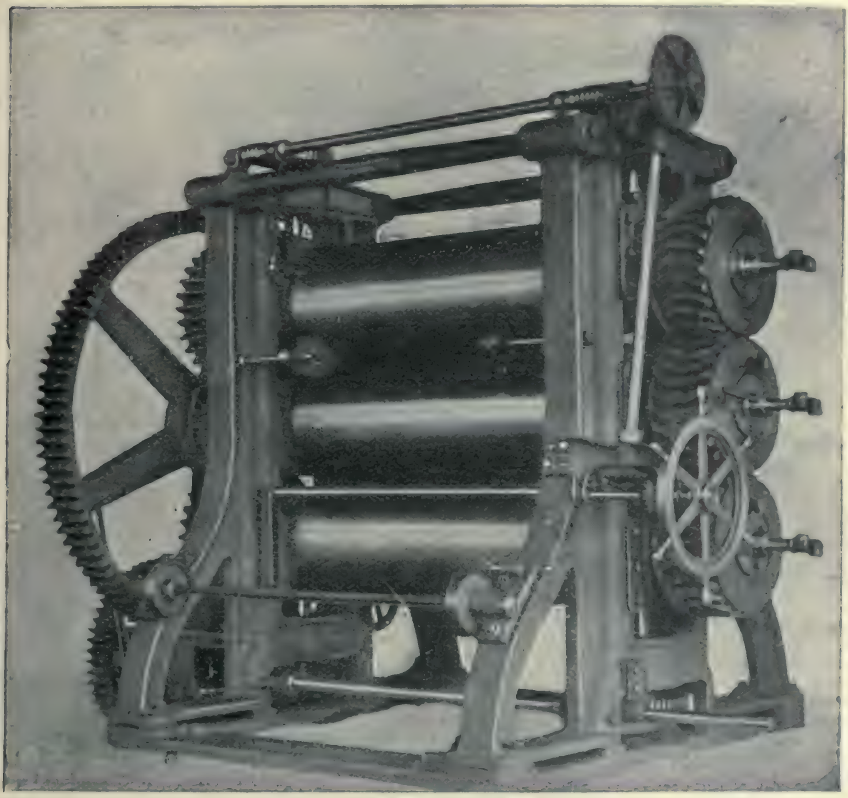


FIG. 60.—Three-roll calender.

rubber blocks with the machine, they may also be laminated into sheet rubber by means of calenders. The calender is a machine much used in the paper and textile trades, and consists essentially of three to six rolls turning alternatively in inverse directions, the one in the direction of the hands of a watch and the other in the reverse direction. In small factories they sometimes use calenders with two hollow rolls. Fig. 59 represents one of these machines of British construction. In the 3-roll calendar (Fig. 60) the middle roll is the driving roll, and is driven directly from an independent motor. The two others of the same diameter as the first, by two straight or helicoidal pinions. The rolls are generally smooth; their speed is not uniform. The top and bottom rolls have some teeth less than the driving roll; the rubber is thus flattened, laminated, and drawn out. The distance between the rolls can be adjusted at will to $\frac{1}{10}$ millimetre by a fly-wheel wrought by hand.

Wooden knives lined with zinc, the shape of which is a triangle, with two curved sides, are fixed between the rolls to limit the size of the sheet. The hollow rolls are generally made of high-class steel, are of an absolutely perfect surface, and are heated by steam or hot water during the whole duration of the operation; they may intercommunicate with this end in view, the heat can thus be varied as required. The temperature of the rolls greatly affects the uniformity of the sheets. Arrangements are therefore made for admitting cold water through the end axis of each roll, and there is a pipe for discharging spent steam. The spent steam may be recovered as it is issued from the rolls by leading it to the water feed tanks or to the washing vats. Before catching hold of the mass by the rolls the foreman calenderer makes sure that his machine is at the right temperature by circulating

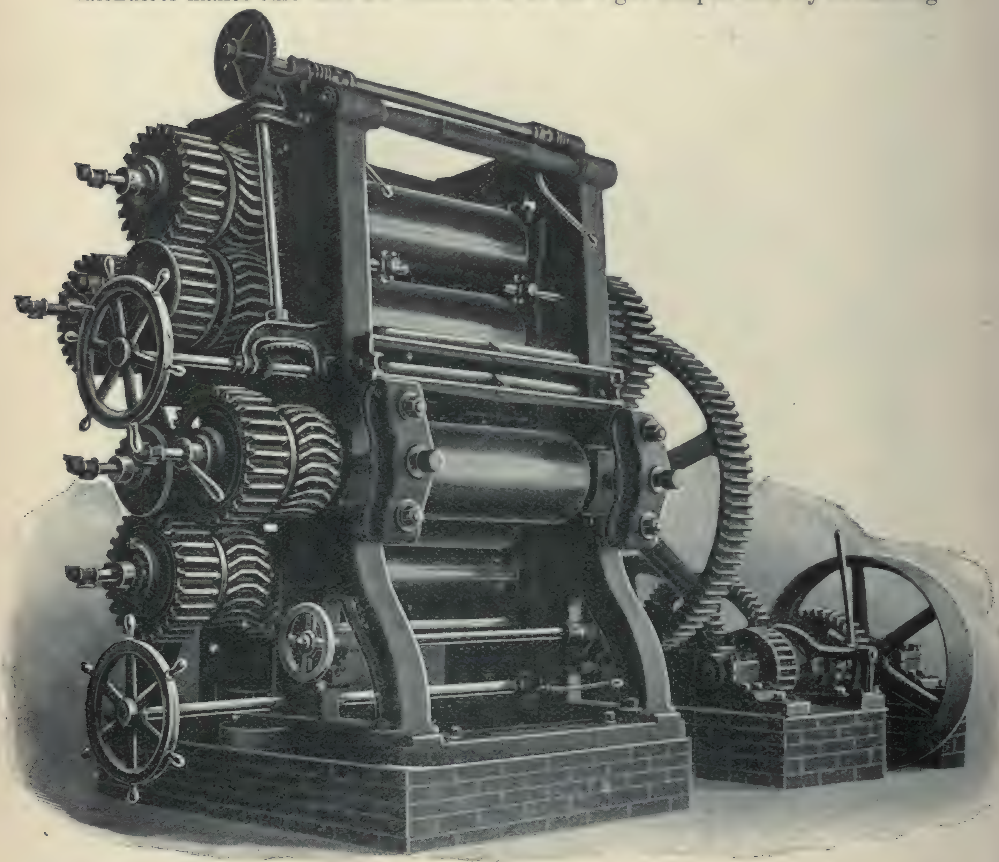


FIG. 61.—Six-roll calender.

steam in it for a few minutes; then, when the cake comes from the mixer sufficiently homogeneous, it is passed, whilst still hot, into the calender, and at first between the two top rolls separated rather far apart at the outset, and through the posterior side the rubber passes slowly with a peculiar noise. The rubber is laminated and converted into a sheet, and is drawn through by the middle roll to undergo a second lamination between the second roll and the third one at the bottom; a vertical section of a calender at work would show the rubber as a sinusoid. The latter is a little nearer to the middle roll than the top one. A small heap is thus formed of the excess of material from the first and second rolls (first lamination). But if small quantities of imprisoned air exist in the original substance, and have escaped in the first lamination, forming an air-bell in the thickness of the sheet,

these bells break their thin envelopes when the excess of rubber forms in a heap in front of the lower rolls. The second lamination therefore yields a sheet free from air-bells. The operation is repeated until a plastic mass is obtained. A short sheet is received on a talced table, but, if of a certain length, the sheet as it issues from the rolls is taken up by a wet cloth, and to prevent agglutination is rolled with it on to a spindle. Calenders equipped with four rolls are likewise constructed. If their working be more complicated and their cost greater, these machines should give a superior product to the preceding, from the fact that the sheet is more pure and freer from air-bells, so dreaded by the manufacturer. Figs. 62 and 63 represent calenders with four rolls. The process may last some hours; webs 50 to 65 feet in length are thus produced, 1·5, 0·5, 0·4, or 0·3 milli-

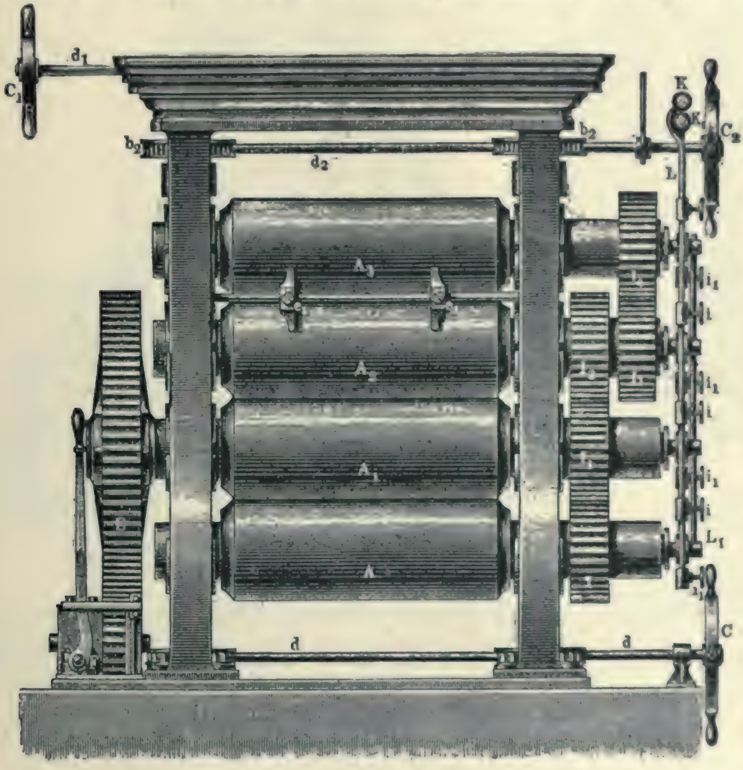


FIG. 62.—Four-roll calender. A, A_1, A_2, A_3, are four cast-iron hollow rolls into which either water or steam can be injected; A and A_3 can be respectively moved closer or further away from A_1 and A_2 by gearing wrought by the wheels C, C_1, C_2.

metres thick. During the operation the thickness is constantly gauged to keep it mathematically exact.

Friction calender.—The friction calender is simply a calender with three hollow rolls, heated internally by a current of steam. It does not differ from the ordinary calender except in its speed. The central roll turns twice as quick as the two others. This result is obtained simply by the use of a cog-wheel, with a diameter equal to half that of the two other wheels geared on the upper and lower rolls. Sometimes the three rolls are not in the same vertical plane. This machine serves to stretch a very thin layer of rubber over the fabrics intended for the manufacture of hose-pipe and transmission belts. A fabric which has been subjected to friction in this way on one of its faces may afterwards be put through the calender to receive

a thicker layer of indiarubber, thus making sure that the calendered sheet will adhere firmly to the fabric.

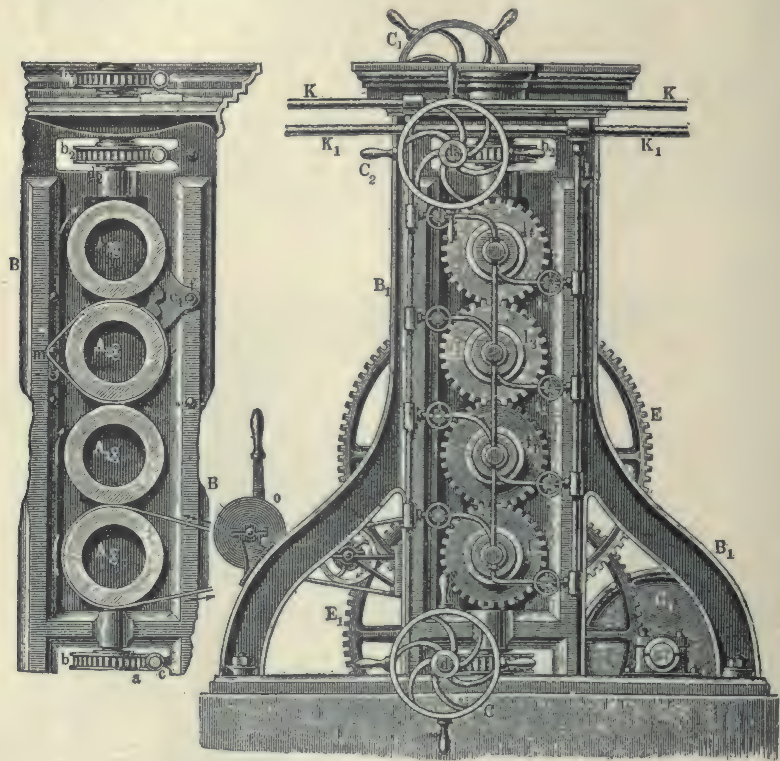


FIG. 63.—Four-roll calender.

The horse-power required to drive calenders.—This force, derived from an independent motor, is rather great, especially when starting with a block of very

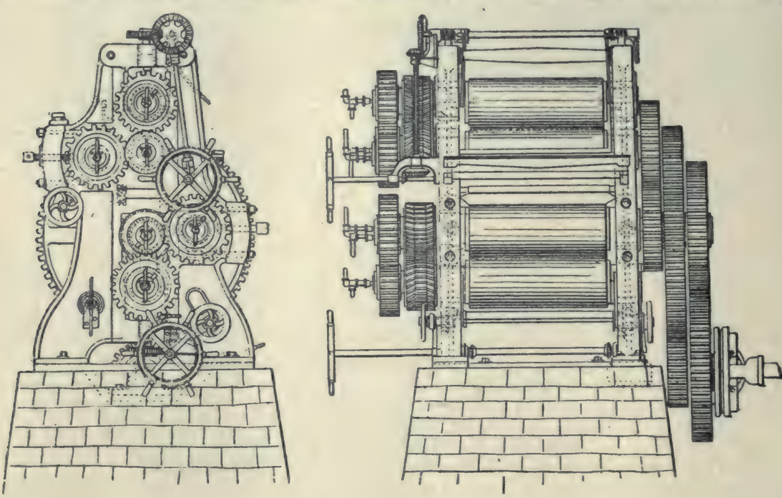


FIG. 64.—Six-roll double-effect calender.

nervous, cold rubber. The speed of the rolls is 10 to 30 revolutions a minute. The horse-power averages 10, but may suddenly reach 20. Large-sized calenders revolve at about 5 centimetres per second, the force absorbed varies from 15 to 25-horse-power. When the number of rolls is four or five, their temperature is brought to 60° to 75° C. From three to four persons are required to attend to a calender, feed the rubber, adjust the rolls, regulate the distance between the knives, gauge the thickness of the sheet, roll it up, receive it, drive the motor, and attend to the clutches. These machines are generally driven by a special adjacent steam engine, an engine with two oblique cylinders with steam of 6 kilogrammes per sq. cm.

Six-roll calender with double effect.—This machine, of more recent invention,

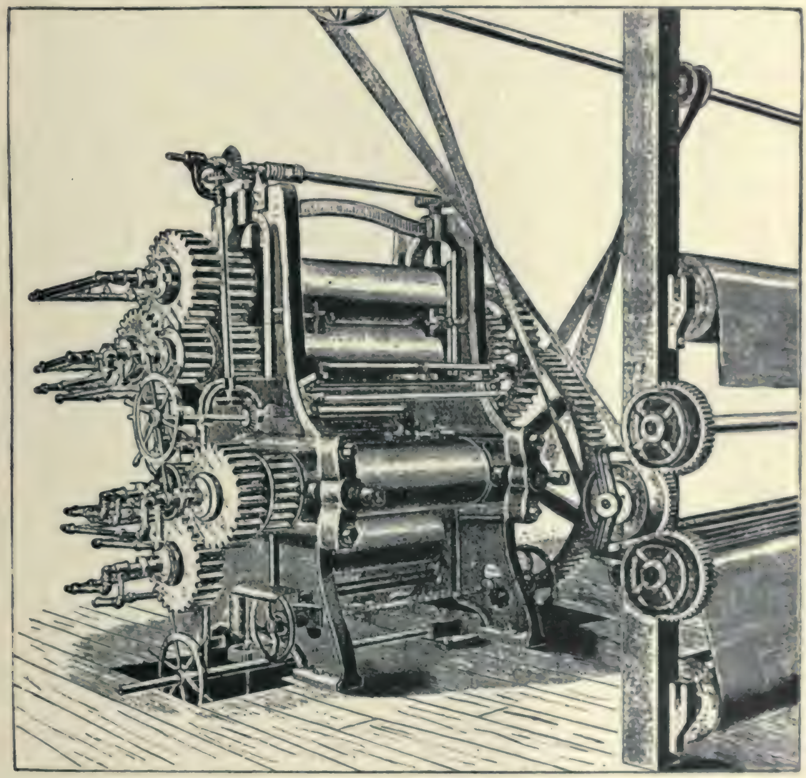


FIG. 65.—Six-roll double-effect calender.

is constructed by the Birmingham Iron Foundry, U.S.A. Figs. 61, 64, and 65 represent this powerful machine in three different positions. Without occupying greater space than the ordinary three-roll calender, it does double work, and may be used either as an ordinary calender, or as a friction calender, or, finally, simultaneously as an ordinary calender and friction calender, according to the work of the factory. A thin sheet of indiarubber may thus be applied simultaneously on the two faces of the same canvas, or it may be used to impart friction on the two faces of the canvas, or, finally, to line the canvas with indiarubber on one side, whilst the other side is simply submitted to the action of friction. As the speed is about 80 feet per minute, the duplex action of the machine produces therefore 160 feet, if one or the same work be done on both sides of the canvas. If care be taken to supply a sufficient quantity of raw material in front of the laminator, of whatever kind it may be, at the

moment when the preceding lot begins to get scanty, a sheet of indefinite length may be obtained.

Gerard's process.—In Gerard's process, the rolls, instead of being heated to 80° C. (176° F.), are heated to 115° C. (239° F.), and the speed is so slow that in passing through the rolls the rubber has time to get annealed over again. The sheets so produced thus preserve and retain the desired thickness to a great extent. The sheet is then raised on to drums, on which it is coiled mechanically, simultaneously with a sheet of calico, so that it cannot come into immediate contact with any other portion, and thus cannot adhere to itself. In another three-roll calender, the sheet, after completion, is rolled on a reel, turning at the same speed as the lower roll, but in a different direction.

Regulating the thickness.—The thickness of the sheet may be regulated to tenths of a millimetre. To ensure uniform and regular working, samples are taken from time to time, and cut not only from the side of the sheet, but also from the centre. They are calibrated with the draw-plate, and the distance between the rolls rectified until the requisite thickness is attained.

Imitation cut sheet.—It has been attempted to impart to the laminated sheet the appearance of the cut sheet; and this has been done, says Chapel, by passing it between bronze and steel rolls, on which fine grooves are engraved, the imprint of which resembles the striæ produced by the saw on the English sheet. The advantages of the lamination and calendering process are that it can be used throughout the whole of the year; it does away with costly methods, and does not entail that enforced locking up of capital during long months of the raw material necessitated by the freezing process, incidental to the manufacture of the English cut rubber sheet. But consumers esteem more highly the articles manufactured from English sheet rubber.

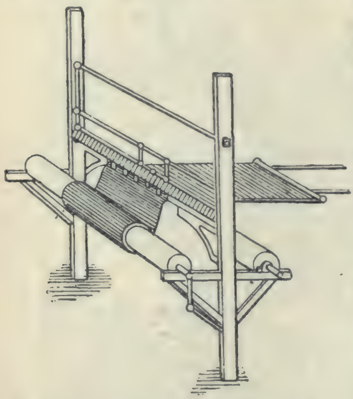


FIG. 66.—Machine for making raised sheet-rubber.

Raised sheets.—The laminated sheet has only lately been used in the manufacture of thread. Formerly, raised sheets were used as an excellent but costly method. As the method of working is still often followed in actual practice, we shall rapidly describe the method of preparing the raised sheet, although mechanical action plays but a subordinate part, and it is more the action of solvents which intervene. To the Para rubber used in this class of work, 2 to 3 per cent. of sulphur is added and then dissolved in a convenient solvent. A machine is used to apply this solution, consisting of two uprights, fixed directly into the floor of the workshop or into a massive bed of cast-iron or of wood, united on the top by a solid cross-bar. On each side of the uprights a wooden roller is fixed capable of turning on spindles supported by bearings fixed on the uprights. The exterior roller is furnished with a crank, wrought by a man or by the factory engine. Just below the inside roll is an iron trough, of the same length as the space between the uprights, which can slide up and down on two grooves on the uprights. The trough contains the solution, and can be raised or lowered according to the greater or less quantity which it is desired to get out of it; when the proper height is reached, it is fixed by bolts. A long band is rolled on the outside roller, which slowly unrolls during the operation, passes between the inside roll and the trough, and there becomes charged with a thin layer of material, and is finally caught by two or more cords stretched horizontally. The coat applied is always very thin, and its thickness is determined beforehand by the distance between the lower part of the feeding trough and the regulator which accompanies it. When the solvent used is carbon disulphide, ten to fifteen minutes suffice to

evaporate it; when light spirits are used, two or three hours are required. The layers deposited are so thin that the operation has to be repeated several times, and it is only by the superposition of several such coats that the desired thickness is attained. The sheet, after treatment with talc, is detached by moistening it underneath by a little solvent, and is then enrolled on the winder. It is now preferably used for the same object in the waterproofing trade. Only evaporation is more rapid, owing to the steam tables

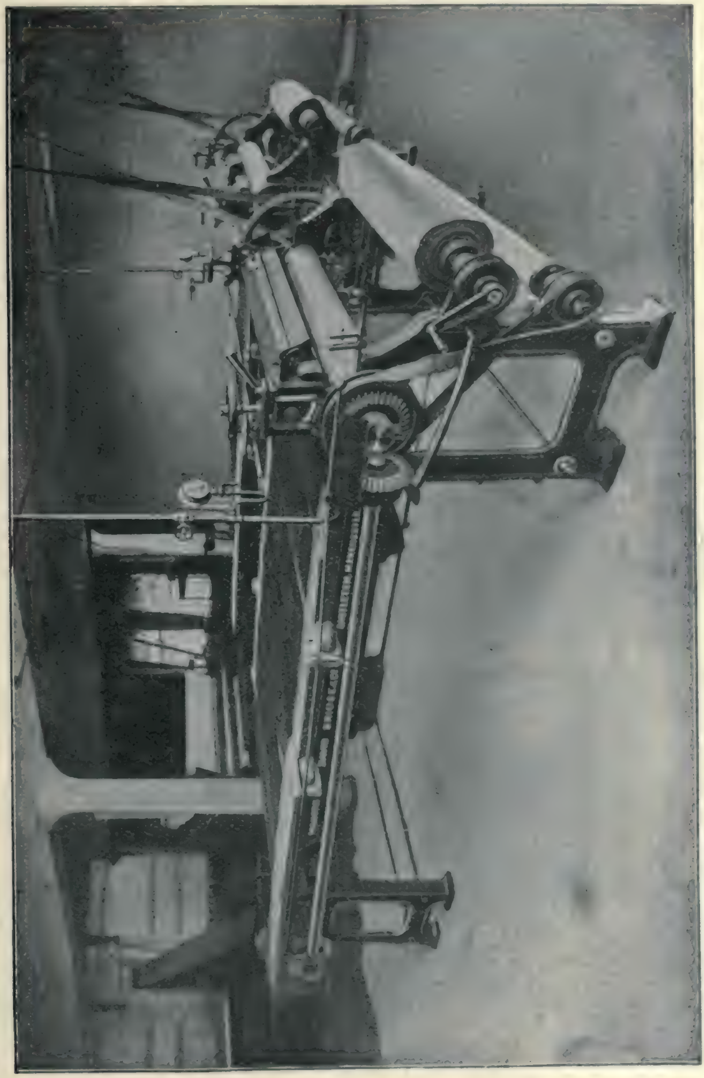


FIG. 67.—Horizontal spreader.

with which the appliances are always provided. The sheets thus produced have only one uniform surface; the lower preserves the grain of the cloth on which it has been laid. *Sollier's process* remedies this drawback. A coating is first laid on the cloth, with the same apparatus as that described above, consisting of paste glue and skin glue, to which a little cane-sugar molasses has been added to preserve its suppleness, and the process conducted as before. The solvent, having no action on the coating, simply spreads over it, without

adhering to it, and it thus becomes possible to produce sheets with a smooth surface on both sides.

Casting sheets on glass.—In the vulcanisation of moulded objects, it is possible, by the use of glass moulds, to obtain straight-away, and without retouching, perfectly polished objects. It is the same with raised sheets, which are obtained as thin as possible and of great transparency by preparing a very dilute solution

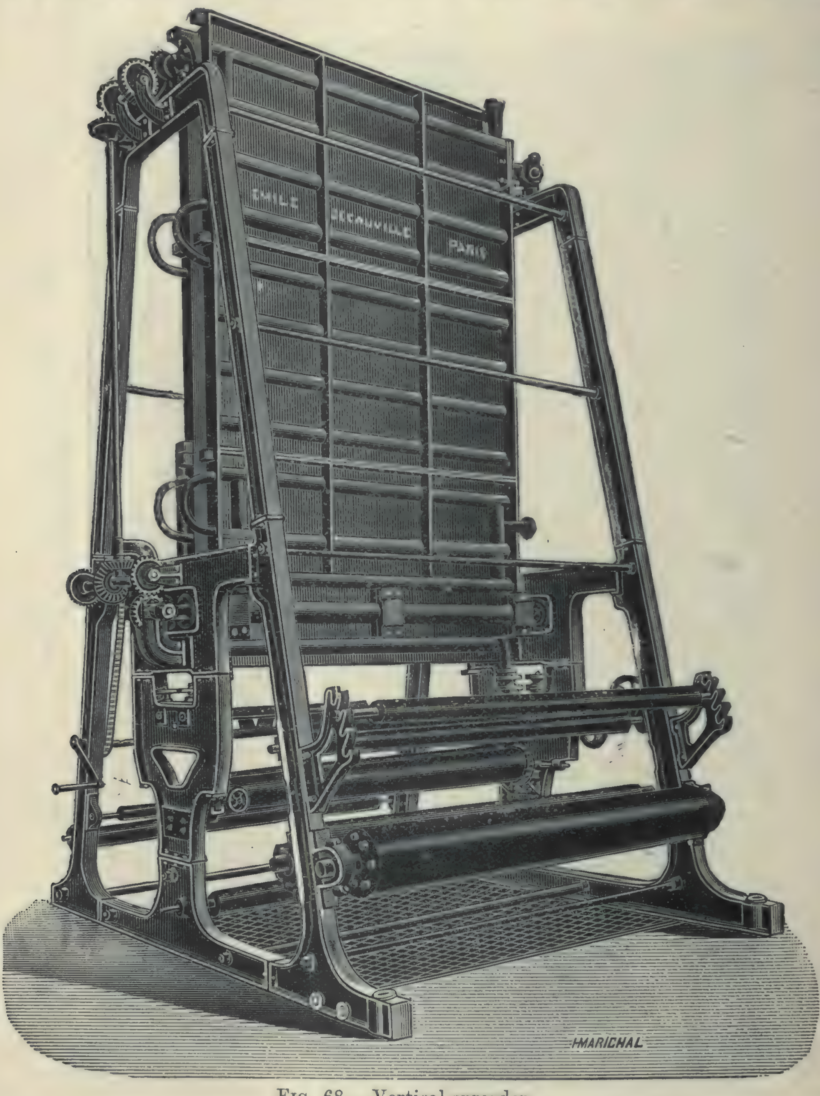


Fig. 68.—Vertical spreader.

of indiarubber (1 of rubber to 15 of carbon disulphide), and spreading this solution on smooth glass. Evaporation, however, must not be too much accelerated, otherwise considerable cold would be produced, with condensation and deposition of the superincumbent moisture, and the drops of water thus produced would spot the facets of the sheets.

Vertical spreader.—The necessity of having to repass the fabric to be waterproofed several times over a hot table is a drawback to the working of the

horizontal spreader. With the vertical spreader the operation only requires one passage through the machine. This machine consists of two cast-steel frames with stout crosspieces. These frames support two hollow cast-iron plates heated by steam, which may be drawn apart or brought near by a mechanical arrangement. The fabrics, after being impregnated with rubber in the tank below the machine, are calendered by passing between two rolls. By means of knives, which can be regulated as desired, the rubber on the two faces of the fabric is equalised, and the latter is led between the hot plates, which evaporate the benzene. The advantage of this machine is that it treats both sides of the fabric simultaneously.

CHAPTER VIII

VULCANISATION OF NORMAL RUBBER

Preliminary considerations.—Defects of natural rubber.—To render the sequel more intelligible, we must recall some defects of natural rubber. (1) *Defects visible on heating.*—All natural rubbers soften rapidly, as soon as their temperature exceeds 30° C. (86° F.) and gets near to 50° C. (122° F.). Their adhesiveness increases in direct ratio with the softening, so much so that at 50° C. (122° F.) the rubber is so sticky and tacky that it is unfit for all the industrial uses for which it is naturally destined.

(2) *Defects on cooling.*—But when the temperature falls to 10° C. (50° F.), rubber gradually and insensibly loses its elasticity, hardens, and at 0° C. (32° F.) becomes so rigid that it is believed to be frozen. Such rapid modifications, within comparatively narrow limits of temperature, constitute great drawbacks to the use of natural rubber. The mere transport of an article made from natural rubber to a hot country or to a cold country suffices to render it almost useless in both cases; in the latter because of its rigidity, in the former on account of its being too sticky and tacky. The same phenomena occur in one and the same locality in consequence of the simple variation of the weather, due to the seasons. Air and light, especially in presence of heat and moisture, deteriorate natural rubber very readily, converting it into a viscous substance, without any of the properties of good marketable rubber: the rubber has perished by oxidation. These original defective qualities would certainly have constituted an obstacle to the use of rubber ever becoming general, and the new industry, now so prosperous, would very soon have been in danger, had it not been for one of those lucky inventions of which the nineteenth century furnished so many examples: namely, *the vulcanisation of indiarubber.*

Action of sulphur and halogens—Sulphur passive to indiarubber in the cold.—Sulphur in no way modifies the properties of indiarubber so long as there is no rise in temperature. But as soon as heat intervenes this passive state gradually gives way, and disappears altogether as the temperature rises.

Payen's researches—Effect of heat on rubber immersed in sulphur.—Payen made the most interesting investigation of this subject. A sheet of rubber, 2 millimetres ($\frac{2}{25}$ of an inch) thick, immersed in a bath of molten sulphur, at 120° C. (248° F.), swells slightly, its pores distend. The rubber absorbs sulphur by capillarity. It behaves as if it had been plunged into water, but the operation is more rapid, owing to the affinity of sulphur for rubber. After a quarter of an hour no appreciable change has taken place in the properties of the rubber, the surfaces of which may yet be amalgamated by contact. The porosity only is lessened. But if the temperature be raised to 130° to 140° C. (266° to 284° F.), and if that heat be continued for thirty to forty minutes, the rubber alters both in appearance and properties, assumes a yellowish tint, and does not amalgamate with itself. Its elasticity is considerably increased and become permanent. Cold does not now cause it to disappear. The same results ensue if rubber, previously mixed with sulphur reduced to an impalpable powder, be exposed to a temperature of 130° to 140° C. (266° to 284° F.). There are still other cases in which the same results are produced. Variable temperatures between the melting-point of sulphur and 160° C. (320° F.) may be used. The reaction is more rapid at a higher tempera-

ture, but experience proves that the best results are obtained by operating at 120° C. (248° F.), and prolonging the operation. *Ebonite.*—If the quantity of sulphur be sufficient, and if the operation be conducted between 150° and 160° C. (302° and 320° F.), there is obtained after a few hours a substance which is no longer vulcanised rubber, but a new product, having neither extensibility nor elasticity; even its aspect is modified—the mixture has assumed a very deep brown colour, and becomes as hard as horn. It is *ebonite.*

Sulphur not the only vulcanising agent.—Elementary sulphur is not the only body which induces vulcanisation of rubber; alkaline sulphides, sulphides of the alkaline earths, several metallic sulphides, sulphur chloride, induce the same modifications in rubber.

Too energetic action of chlorine, fluorine, iodine, and bromine.—Chlorine, fluorine, iodine, and bromine act similarly to sulphur. But these bodies are much more volatile than sulphur at the ordinary temperature; their action is more energetic, often too energetic to attain in a uniform manner the desired object. Sometimes this object is overdone, sometimes vulcanisation is insufficiently effected; sometimes, again, the reaction is rapidly destroyed by the volatilisation of the vulcanising agent.

Sulphur cheap and easily handled.—These processes cannot be easily adopted in practice. Sulphur gives satisfactory enough practical results; it is cheap and easily handled. It would be idle to resort to other processes, the application of which is difficult without yielding better results. The examination of vulcanisation by those secondary bodies will therefore be deferred, retaining only sulphur or its derivatives, which, moreover, present a sufficiently extensive field for investigation. Of the innumerable methods of vulcanisation by sulphur and its derivatives proposed and attempted, whether in Great Britain, France, America, Germany, or other countries, we shall only examine and describe those which deserve more especially to fix the attention of manufacturers, with a brief criticism of these different methods, showing the advantages and disadvantages of each; the machinery and plant most generally used in the vulcanising industry will also be described, terminating this chapter with a discussion of the theory of vulcanisation.

The hot and cold processes of incorporating the sulphur.—The most important method hitherto considered is that based on the use of natural sulphur. It is divided into two different processes, according as the sulphur is incorporated (1) in the hot (Goodyear's process) or (2) in the cold state (Hancock's process).

1. *Goodyear's process—Vulcanisation of rubber by natural sulphur.*—This, the most generally adopted process, is based on cold mixing of a predetermined quantity of sulphur with rubber, and on *baking* or curing, *i.e.* the transformation of this mixture into vulcanised rubber by a predetermined quantity of heat. This process is certainly the most rational, because known proportions of sulphur can be incorporated with the rubber, and nothing is left to chance. Moreover, it almost always yields results which cannot be attained by other processes. The rubber, masticated and dried, as already indicated, is put through the mixer with 7 to 10 per cent. of sublimed sulphur (flowers of sulphur). Rubbers are even met with in commerce vulcanised with only 2½ to 3 per cent. of sulphur. But the quantity of sulphur varies within the wider limits, and certain manufacturers have been known to use as much as 25 per cent. The first proportion is amply sufficient, and even 6 per cent. of sulphur has given excellent results. The excess, when not prejudicial, can only be regarded as an inert make-weight. *Homogeneous mixing essential.*—The mixing must be perfect to ensure success, and the mass must form one homogeneous whole. Too much care cannot be bestowed on mixing so as to obtain a homogeneous mass. Four or five kilogrammes (say 9 to 11 lb.) of washed rubber are passed repeatedly through the hot rolls, diminishing the space between them as the operation proceeds. As it issues from the roll, the sheet is dusted for the first time with sublimed sulphur, rolled upon itself, and again passed through the mixer. This operation is repeated as often as necessary to exhaust completely the amount of sulphur to be incorporated and obtain a really homogeneous mass.

This mass, still a mere mixture, is *wrought* in the ordinary way for conversion into threads, sheets, tubes, shoes, or any other object of definite shape. It is only under this final shape that the objects are transformed by heat. They are introduced into a hermetically sealed boiler, where steam is injected at a suitable pressure, generally $3\frac{1}{2}$ to 4 atmospheres. A sojourn of three to four hours in the boiler is sufficient to produce vulcanisation. In certain cases, the boilers are replaced by a hot stove heated from 130° to 150° C. (266° to 302° F.). Varnished indiarubber boots are vulcanised in this way (as steam would destroy the brilliancy of the varnish); so also are certain waterproof garments. But whether boilers or stoves be used, the same result is attained: the indiarubber is acted on by the sulphur in the desired dose, and the latter is distributed throughout the mass with almost mathematical uniformity.

Goodyear's process costly.—The most serious objection to Goodyear's process is that it involves great initial outlay, and a large amount of labour for its perfect execution. It is therefore costly, and is not readily available by the small capitalist; but that defect, not easily remedied, need not be dwelt upon further.

The excess of sulphur effloresces on the surface of the object—Injurious effect—Remedy.—A more serious criticism against Goodyear's and also the bath process, is that rubber articles vulcanised directly by sulphur always contain an excess thereof, which, when the operation is finished, has a tendency to separate out, and cover the surface of the object with a greyish white efflorescence, disagreeable to the eye, touch, and smell. This substance (simply sulphur in extremely small crystals) may hasten the rapid decay of the manufactured article. In contact with the moisture of the warehouses, the sulphur oxidises to sulphuric acid, always injurious to rubber. Washing with alkaline lye is the usual remedy; but if contact be prolonged, which is nearly always necessary, washing gives rise to another defect, the surface of the article is exposed too much, and is partially devulcanised, so to speak, and some of the defects, inherent in normal rubber, are restored to it.

2. *Hancock's process*[1] (*the bath process*)—*Differentiation from Goodyear's dry mixing process.*—Instead of mixing sulphur with rubber at a comparatively low temperature, and then submitting this mixture to the heat of the steam from a boiler or to the hot air of a stove, the heat of melted sulphur is utilised to ensure vulcanisation, *i.e.* instead of baking or curing with steam or superheated air, the manufactured objects are steeped in a bath of molten sulphur. Mixing and curing proceed simultaneously.

(1) *Preliminary drying.*—But prior thereto the articles must sojourn from twenty-four to thirty-six hours in a hot stove, so as to consolidate the joints and evaporate traces of the solvent used in the manufacture of the article, otherwise vulcanisation by Hancock's process would yield blowholes, which would deteriorate the goods.

(2) *Immersion in bath.*—When perfectly dry the articles are immersed in molten sulphur at 130° to 135° C. (266° to 275° F.). But as they are much too light to remain immersed by their own weight, they are loaded by small weights called *reglettes.* Small pieces of indiarubber are immersed at the same time as the articles, and so arranged that they can be withdrawn at will. These fragments, or samples, enable the progress of vulcanisation to be watched. They ought, as far as possible, to have the same thickness as the articles to be vulcanised; the indications which they furnish have thus a real value for the operator, who requires to have had great experience, so that by simply inspecting the samples he can judge how far vulcanisation has advanced. When the articles have been immersed in the bath, vulcanisation is not long in starting. The rubber first absorbs the sulphur by capillarity, and so increases in weight by one half. Its colour then begins to change: from brown it changes to orange. Taken out of the bath in this state after twenty minutes' immersion, the rubber is still too soft, and still possesses the property of uniting with itself; the normal rubber has not been chemically modified. But, in a few moments, after the saturation of the pores, the real reaction starts; it is complete in two or three hours; the phenomena is accompanied

[1] British Patent, 9952; 1843.—Tr.

by the disengagement of sulphuretted hydrogen from the mass of the liquid which does not occur in the beginning. Chemical reaction takes place, for if the operation be prolonged the substance becomes as hard as wood, and is transformed into *ebonite*. When the workman thinks the substance sufficiently vulcanised, he immerses it as quickly as possible in cold water. He exhausts it and thus frees it from the excess of sulphur that covers its exterior, which splits up by the sudden cooling, so that it only adheres slightly to the rubber. A slight scraping with a metal blade suffices to free the article from it.

Vulcanised goods liable to sulphur efflorescence—Remedy.—But, nevertheless, rubber so treated always retains, as in Goodyear's process, a certain excess of sulphur over and above that required for vulcanisation, which forms an inert substance, more injurious than useful. This excess is gradually exuded from the interior of the mass as a white powder, forming a coating on the surface of the object vulcanised. It is easy to free it from a certain portion of this excess of sulphur if, as soon as vulcanised, it be passed through a boiling solution of caustic alkali. The excess of sulphur is rapidly converted into alkaline sulphide, and simple washing afterwards suffices to eliminate the resultant sulphides.

3. *Sublimation process, namely, vulcanisation by sublimation.*—Hancock proposed another modification, based on the simultaneous action of steam and sulphur vapour, which effects vulcanisation in an hour and a half, according to thickness of pieces. The sulphur bath is still used, but no longer as a vulcaniser, but in place of steam or of the air-oven for vulcanisation of certain moulds. Alongside these two processes, based on the use of sulphur acting directly on the rubber, it is convenient to quote—

(1) *Parkes' process, or the steeping process—Cold process.*—It consists in treating rubber with sulphur protochloride. Discovered by Parkes (British Patent, 11,147; 1846), it is now frequently used, especially to vulcanise small thin objects. The process works in the cold and very rapidly. 2·5 lb. of sulphur chloride are dissolved in 100 lb. of pure, perfectly anhydrous carbon disulphide. The articles to be vulcanised are immersed in this liquid from a half to three minutes, according to their thickness. When taken from the vulcanising bath, the article is dried at a temperature of about 25° C. (77° F.), again steeped in the bath from a half to one minute, then washed, first with a very dilute solution of sodium carbonate, then in pure water, and finally dried. This process is only applicable to small thin objects. Thicker articles must be steeped longer, to let the liquid penetrate, but then there is risk of overdoing it; the rubber may be burnt.

(1*a*) *The inventor's and Gerard's modifications.*—Parkes therefore proposed only to use $\frac{1}{2}$ part of sulphur chloride for 100 parts of carbon disulphide, and to prolong or repeat the process. G. Gerard recommends to use only the first proportions, *i.e.* $2\frac{1}{2}$ per cent. of chloride, but to steep the articles immediately they come out of the bath in cold water, and to let them lie there for some time. The chloride thus has time to penetrate the rubber, whilst the superficial part already vulcanised is no longer liable to become brittle, the excess of sulphur chloride on the surface is transformed, in contact with water, into hydrochloric acid, sulphurous acid, and free sulphur. The steeping process is distinguished by great simplicity and extreme rapidity. It requires no complicated plant nor costly raw material. It is specially adapted, moreover, for surface-curing in the manufacture of small objects of cut rubber, tobacco pouches, injectors, syringes, tubing, rings, etc. But it cannot be used for articles exceeding 4 millimetres (say $\frac{1}{6}$ of an inch) in thickness, otherwise vulcanisation will only deteriorate the goods profoundly, cause them to become fragile, and break with the slightest effort.

Dittmar points out that the method of working since Parkes' time has been changed. According to Marzahn, the articles are dipped one to three minutes in a solution of sulphur chloride in 40 to 50 parts of carbon disulphide, then dried. If necessary the operation may be repeated. Hoffer recommends the following mixture for thin objects:—Sulphur chloride, 1 part; carbon disulphide, 30 to 40 parts; time of dipping, sixty to eighty seconds. For thicker articles, sulphur chloride,

1 part; carbon disulphide, 30 to 40 parts; time of dipping, three to five minutes. For still thicker articles, the dipping must be repeated as often as necessary to complete the vulcanisation. Too long steeping induces hard brittle surfaces. Washing after steeping prevents the sulphur chloride in excess from continuing its action. Water decomposes sulphide chloride; the sulphur separates partly as such, partly as sulphurous and hyposulphurous acids, the ratio of the two latter depends on the amount of water. The chief drawback of the cold process of vulcanisation is due to the injurious effect of the vapours of sulphur chloride and carbon disulphide on the workmen. Attempts have been made to substitute petroleum spirit, which should be anhydrous, for carbon disulphide. Dittmar tried to determine the influence of the time of steeping on the tensile strength and elasticity of Para rubber. He cut small samples 5 centimetres long from a large band 2 metres long by 3 centimetres wide and 7 millimetres thick. These samples were dipped into the vulcanising liquid, consisting of sulphur chloride, 1 part; carbon disulphide, 80 parts. The samples were stretched by Delaloe's dynamometer. After drying, the measurement of the elongation was made on 1 centimetre.

Table XXXIII.—Variations in Tensile Strength of Indiarubber Cured by Parkes' Process according to Duration of Steep.

Duration of Dipping in minutes.	Breaking Load in kilogrammes.	Elongation at the point of Rupture in centimetres.
1	14	3·6
2	15	3·9
3	15·2	8
4	15·62	6·2
5	16·25	5
6	12	3·8
7	15	3·7
8	15·25	3·8
9	16·5	7·4
10	18·5	6·2

The pure para gave 7 kilogrammes and 2·2 centimetres. The tensile strength therefore increases up to five minutes, then diminishes, then increases after five minutes. The elongation increases up to four, then lowers; after eight minutes it again increases.

Recommended by Fawsitt.—In a research which merits attention, Fawsitt in 1889 specially examined Parkes' process and became an ardent apostle of it. This chemist attributes the complaints as to the durability of the rubber to defective manufacture, and he quotes samples of rubber vulcanised by this process having preserved all their elasticity and other properties after twenty years from their despatch from the factory. Vulcanisation by sulphur chloride dissolved in carbon disulphide presents numerous difficulties, only surmountable by observing numerous precautions. The first of these is to use only sulphur protochloride S_2Cl_2, and never the perchloride SCl_2, the action of which is too energetic. One can thus use more concentrated solutions, the better to attain the end in view. But even if protochloride be used, it is extremely unstable, especially in the light, so it is necessary always to have a standard solution ready to make certain that the protochloride does not vary from one operation to another. Fawsitt was perfectly able to obtain vulcanised articles of excellent quality, but the dislike of the generality of manufacturers for this process is none the less justified. A certain solution of sulphur chloride which succeeds very well in the first instance may be altered by the use of imperfectly dehydrated carbon disulphide, or imperfect storing in a spot badly protected from light and moisture. Vulcanisation with such a solution will not produce the original effect, and the negligent or clumsy worker will simply have employed a decomposed liquid, containing only

hydrochloric acid and a little sulphur deposited on the bottom of the vessel. Vulcanisation will therefore either not be effected at all or only imperfectly.

The toxic effects of carbon disulphide.—Again, the operation, as described by Parkes, is dangerous to the health of the workman, and all the possible ventilations proposed by Fawsitt as preventatives can only increase the evil instead of remedying it.[1] The carbon disulphide which is used as a vehicle does not act from its toxic effect, but by the intense cold which it generates during its rapid evaporation. Rapid evaporation being increased by energetic ventilation, cerebral congestions are frequent and fatal.

Petroleum spirit and benzol as vehicles instead of carbon disulphide.—Petroleum spirit should thus be substituted, as proposed by Humfrey, for the vehicle used by Parkes, or, better still, benzol, which gives excellent results, provided it be perfectly dehydrated.

Vulcanisation by the vapour of chloride of sulphur alone.—But there actually exists a much more inoffensive process of vulcanisation by sulphur chloride. As in cloth bleaching, a kind of sulphurator is made, lined with lead, and perfectly tight; the objects to be vulcanised are suspended therein. The sulphur chloride is placed in a bowl, standing over a chafing-dish, with a fire in it, and the sulphurator is closed. The operation goes on without any further intervention, and the simple washing of the objects in water, to which a little ammonium hydrate has been added, after they come out of the leaden chamber, removes useless and injurious substances which have formed on the indiarubber during the reaction. Parkes' process, or vulcanisation in the cold by sulphur chloride dissolved in carbon disulphide, petroleum spirit, or benzol, as well as the process by the vapour of sulphur chloride alone, were, until recently, used to the exclusion of all others for the vulcanisation of cloth for waterproof garments, or, to speak more correctly, for the vulcanisation of the thin layer of rubber which renders the stuff impermeable.

Vulcanisation by dry steam.—Since then it has been thought right to abandon the cold process, as well as the process of vulcanisation by the vapour of sulphur chloride alone, in favour of vulcanisation by dry steam. Three houses only in France employ this new process; Britain (more especially Scotland) counts a rather greater number of factories which have adopted the vulcanisation of fabrics by dry steam; but it is particularly in America, where the process was invented, that the method is most employed.

Litharge a necessary adjunct.—This vulcanisation, in a special oven, does not yield good results unless litharge intervenes with the sulphur, the litharge acting, so to speak, as a drier. Without litharge the vulcanised piece would remain greasy and tacky to the touch. Until quite recently only black coloured rubbers, or rather fabrics, could be obtained in this way.

It is only lately that a French house has produced by the dry steam process vulcanised cloth of all shades, with the exception of a perfect white. Unfortunately the process is kept secret, and it is impossible to give any particulars regarding it.[2]

Fawsitt's experiments and researches on vulcanisation by dry steam in presence of iodides.—Mr. Charles A. Fawsitt, the numerous researches of whom on the vulcanisation of indiarubber by sulphur chloride we have already had occasion to mention, gave in the *Journal of the Society of Chemical Industry* for 1894 the results of a remarkable research on the new process of vulcanisation by dry steam in the presence of iodides.

Whilst reserving our opinion on the methods adopted and more particularly extolled by the author, experience has not everywhere given equally satisfactory results, and the subject is yet too new to be completely elucidated. Fawsitt thinks that the best way of enumerating the reasons which have induced British, American, and French

[1] See also the *Risks and Dangers of Various Occupations* (Scott, Greenwood & Co.), pp. 168–172, for further details of the industrial hygiene of rubber manufacture.

[2] The litharge is possibly replaced by a manganese drier.—TR.

manufacturers to adopt this new vulcanisation process, is, first of all, to explain the advantages and disadvantages of both processes. *The advantages of the cold process* are:—1. The production of what is called the transparent layer, still so much appreciated, although a little less so for simple woven goods. 2. The rapidity and the cheapness of this process compared with the dry heat process. What is here meant by cheapness does not apply to the composition itself, but simply to the cost of manipulation. 3. *The non-efflorescence of goods treated in the cold*, a very important point, which has not been satisfactorily explained. As bearing upon this, a short digression may be made and one or two points connected with efflorescence which may be of interest mentioned.

Points connected with efflorescence.—How is it that with rubber treated in the cold we can use 9 to 10 per cent. of sulphur without fearing efflorescence, whilst in the dry heat process 3 per cent. would be dangerous? Some say it may be explained in this way: the rubber has not been treated above the melting-point of sulphur. Fawsitt tested this assertion by heating three pieces of waterproof, prepared in the cold, and containing more than 6 per cent. of sulphur, above the melting-point of that body, but Fawsitt did not get any efflorescence.

Disadvantages of the cold process.—1. The principal reason which has induced manufacturers to adopt the dry heat process is that often the cold process deteriorates the goods, and that from causes which have not been explained. This deterioration is generally attributed to the oil contained in the stuff, but in that case it is only accidental; without doubt, manufacturers make defective mixtures, but they prefer to attribute the fault to others. 2. The injurious action of the vapour of carbon disulphide on the workpeople attending the plant. In some manufactories this action is reduced to a minimum, and does not give rise to any difficulty, but it is not so in the generality of factories. 3. The greater number of manufacturers say that goods prepared in the cold do not stand hot climates nor cold climates so well as might be desired. In hot climates the intense light, the heat, and the emanations from the ground exert a powerful decomposing action. Light is the principal agent of this alteration. 4. It is not possible to adulterate rubber so easily when sulphur chloride is used, which, in this age of cheapness, is a matter of great importance. Rubber vulcanised in the cold is better vulcanised than by any other way. However, is it easy or even possible to accomplish in the case of cloth what can be done with a sheet of rubber?

Advantages of the dry heat process.—The advantages of the dry heat process are explained, for the most part, by the disadvantages of the cold, because—1. There are few complaints as to damaged goods, and cloth with a proportion of oil may be used which could not be done in the cold process. But if the damage arising from the action of the stuff on the coating of rubber may be greatly reduced in the dry heat process, it must not be inferred that this damage does not exist; and on black and brown calico, a good layer of rubber decomposes within twelve months; that is due to the mordant and the colours used. 2. The use of carbon disulphide is avoided. 3. The coating of rubber resists great cold and extreme heat better than that vulcanised in the cold. 4. Cheapness.

Disadvantages of the dry heat process.—As far as the disadvantages of the dry heat process are concerned, we have—1. The danger of efflorescence, the principal cause of the complaints addressed to manufacturers; and as black paramattas become more and more fashionable, this is a very important point. 2. The space occupied by the stoves. 3. The cost of vulcanisation for a given length of stuff is double that of the cold process; this drawback is compensated by the possibility of making a cheaper coating, but the advantage is none the less in favour of the cold process. 4. The impossibility of producing a transparent coating which is both supple and elastic. It may be asked why the dry heat process is not used for waterproof goods, since it is used for other objects. It is because although the rubber is well applied, and with less danger of efflorescence with dry heat, this process would be fatal to the colours of the stuff, and to the stuff itself. Before the invention of the dry heat process, the steam process

was used, but never on the larger scale, except for black cloth and white cloth. When manufacturers who were accustomed to work by the steam process and by the cold process commenced to use the dry heat process, numerous difficulties arose, which were not easily overcome. If, therefore, we take a piece of rubber mixed with 4 per cent. of sulphur, and heat it to 121° C. (249·8° F.) in a stove with dry heat, the rubber softens and becomes useless; but if the same piece of rubber be heated in steam, it is satisfactorily vulcanised. It is thus necessary to make different mixtures for each kind of coating. Moreover, the difficulty of both preventing efflorescence and producing satisfactory vulcanisation has caused much annoyance, and experience has often been gained by the loss of customers, the weather constituting the factor which affects the sale of rubber goods most strongly. Again, persons accustomed to buy transparent, well-finished garments, velvety to the touch, are not easily induced to buy simple woven goods with a dark coating awanting in softness to the touch, and not so elastic. Of course, in the case of light-coloured stuffs it is not so important to avoid efflorescence, but in the case of black or dark stuffs it is necessary to avoid it completely. The evil may be avoided by using a high temperature or a continuous heat, but then the stuff would suffer. It has been found that woollen stuff is attacked slightly at about 116° C. (240·8° F.), hence comes the importance of heating gradually and for a longer time. With the coating applied by the dry heat process the temperature cannot be allowed to go below 114° C. (237·2° F.), the melting-point of sulphur. Hence comes the necessity of bringing the heat of the stove as promptly as possible to this temperature. As far as the duration of the heat is concerned, it depends entirely on the composition of the coating, but it requires on an average one to two hours at 116° to 118° C. (240·8° to 244·4° F.).

The use and construction of stoves require much practical knowledge. Steam at 4½ kilos. (say of 10 lb.) pressure would be more than sufficient to produce a temperature of 114° C. (237·2° F.), supposing no heat was lost by radiation; but in the case of large stoves the pressure is raised to 27 kilos. (say 60 lb.). It is more economical to work with even greater pressure, for then the heat may be brought more promptly to the melting-point of sulphur, and more work can therefore be done in a given time.

Some years ago Fawsitt's firm were asked to supply a mixture capable of giving a transparent coating with dry steam. He made a number of experiments, which ended in the production of a substance which answered well for the end in view, and applicable not only for this special kind of work, but also to others which had not been foreseen. When the laboratory experiments were finished, the North British Rubber Company, Edinburgh, which had the longest experience of the dry process of any firm in Great Britain, were good enough to make practical tests, and, in 1891, under the supervision of Mr. A. Douglas, they succeeded. It was proved that this substance was suited for the production of transparent coatings, and it was introduced into the manufacture of such objects as fishing stockings. There are therefore to be found on the market objects now being manufactured by this firm, the most important of which is the fishing trousers. The rubber is exceedingly supple; by exposing the stuff to not too high a temperature, and for a short time, the risk of acting on it is diminished. Two transparent samples were sprinkled with the same rubber as the fishing stockings. The silk sample was sprinkled in July 1891, and vulcanised for three-quarters of an hour at 116° C. (240·8° F.). Another silk sample was sprinkled in June 1893, and heated for one hour only at the same temperature. These samples, especially those which were very slightly sprinkled, are supple and pleasant to the touch and of a beautiful appearance. Two samples of coloured sheet rubber were prepared by Messrs. W. Warne & Co. These samples only contain 2 per cent. of vulcanising agent, that is to say, of the iodides of the heavy metals mixed with sulphur. In his patent Fawsitt claims all the compounds of iodine and bromine. He found, however, that the iodides and the bromides of the heavy metals yield the best results; that sulphur was necessary, and that, without it, it was impossible to succeed.

Deductions and conclusions.—The following are the points established in these experiments:—1. The minute amount of the compound necessary to ensure complete vulcanisation. The iodide might be reduced to $1\frac{1}{2}$ per cent., the sulphur being 2 per cent.; $3\frac{1}{2}$ per cent. of mixture does not in any way affect the transparency of the rubber. 2. The comparatively low temperature required for complete vulcanisation. This point seems important, for most manufacturers experience great difficulty in vulcanising in a satisfactory manner at a temperature which does not injure the stuff. The extreme sensibility of the vulcanising agent to heat was rather a drawback at the beginning of the experiments, because too near an approach was made to the operations made with mixtures for dry heat. In the first trials, 15 per cent. of iodine and 6 per cent. of sulphur were used, and what was astonishing was that these samples were vulcanised between 93° and 96° C. (199·4° and 204·8° F.), much below the melting-point of sulphur, which was quite unusual, and proves that the reaction which takes place is quite different from that which occurs in the ordinary process, where there is no apparent action below 114° C. (237·2° F.), even although there be a considerable proportion of vulcanising agents. Naturally, when such a large proportion of vulcanising agents is used, a large quantity of this product remains useless, to such an extent that it may later on affect the indiarubber. This was proved by heating a piece of rubber of this kind between 116° and 118° C. (240·8° and 244·4° F.), but for thirty-nine minutes only. The piece became quite hard. The property of the vulcanising agent of acting below 114° C. is not of any great importance at present, but it may receive a useful application later on. 3. The rapidity of the operation was surprising, for half an hour sufficed when 3 per cent. of vulcaniser and 2 per cent. of sulphur were used; when a larger quantity was taken, and a high temperature, vulcanisation was effected in a few minutes. With 15 per cent., ten minutes' heating at 121° C. (249·8° F.) was sufficient. Rapid vulcanisation is distrusted; that is quite natural, for the method generally used requires no less than two hours at 114° C (237·2° F.). It was found that, with the new compound, it was best to only use a small proportion, and to prolong the heat; but one hour appeared to be sufficient for all ordinary purposes when 1 to 3 per cent. of compound was employed with 2 per cent. of sulphur. With these proportions the vulcaniser appeared to be exhausted after one hour's heating. To prove it, Fawsitt cut a piece of mixed rubber in two, and heated one portion during an hour at 116° C. (240·8° F.) and the other for three hours; at the end of that time both were equally vulcanised. The vulcaniser, by acting so rapidly at so slightly elevated a temperatute, is very economical, from the fact that, in a given time, a stove can do more work. That is the grand advantage of the dry steam process. Mr. Waddington has taken out a patent for a continuous stove, and Messrs. Charles Macintosh & Co. and other manufacturers use it. In this stove the stuff is drawn slowly along; it rises and falls a great number of times before being rolled on a cylinder outside. It would appear that here fresh progress had been made, because by this system the stuff can be tested when desired, and the speed of the rolls regulated according as the rubber is vulcanised too much or to too small an extent. This system also prevents the false folds (kinks) produced in the ordinary stoves, and will be specially applicable when the new vulcanising agent is used, as it is more sensible to heat than any of the substances used in ordinary working. A difficulty presented itself at the outset, which caused some annoyance, but a way was found of obviating it. On wool, vulcanisation was satisfactorily effected; not so with calico, dyed brown or black. On one occasion calico with black and white squares had been operated on. On the black the coating was soft and not sufficiently vulcanised; on the white it was perfect. As black woollen stuff was exempt from this peculiar action, it could only be due to the different way in which the colours had been fixed in the two cases. The failure with calico was thought to be either due to the mordant alone, or to the mordant combined with the dye; with cloth of many colours it was difficult to say which were those which exerted

an injurious influence. Fawsitt therefore procured a cotton thread dyed with different colours, and made woven strips of it, on which he spread the rubber paste, containing a proportion of vulcaniser more than sufficient to vulcanise it. After being treated for two hours between 116° and 118° C. (240·8° and 244·4° F.), it was found that the coating on the whites, the blues, the greys, and certain shades of brown were perfectly vulcanised, but that the blacks and the deep browns were not sufficiently vulcanised. As it was the stuff dyed black which had given the greatest amount of trouble, Fawsitt tried to find out the cause of it. He commenced by taking the opinion of an experienced dyer to try to find out what had been the process employed in the dyeing of the thread. After a critical examination he said the mordant was an iron mordant, the tannin "prepared," and the dye logwood. Fawsitt then took three pieces of white calico—No. 1 was steeped in a solution of iron mordant; No. 2 in a solution of tannic acid; No. 3 in a solution of logwood. Fawsitt then dried them, and spread over their surface a paste of rubber of the same composition as that previously used. After vulcanisation Fawsitt dried them at 116° C. (240·8° F.), and in each case the coating was of good quality; thus, taken separately, the reagents did not hinder vulcanisation. Three pieces of stuff were cleaned and treated as follows:—No. 1 was dipped into the iron mordant and then into the tannic acid. No. 2 was dipped into the iron mordant and then into the logwood extract. No. 3 was dipped into the iron mordant, then into the tannic acid, then into the logwood extract. After drying, the rubber paste was spread on their surface and they were treated as formerly. No. 1 was vulcanised, but Nos. 2 and 3 were not vulcanised, which evidently proved that the fault lay with the compound which was formed between the oxide of iron and the colouring matter of the logwood. Want of time prevented this subject being further studied, and the cause of this action ascertained. How could this dyeing mixture influence the iodide or the mixture of iodide and sulphur to the point of preventing the vulcanising action? It seemed almost that this tinctorial compound acted on the sulphur, or combined with it so as to withdraw it from the action of the iodide; for the addition of supplementary sulphur was an antidote, so far as vulcanisation was concerned; but was the use of this addition admissible in the case of black stuff, on account of the danger of efflorescence? A possible explanation might be that the cloth which is generally sold might contain a little mordant removable by washing or greasy matter. Accordingly, pieces of stuff containing a good mixture of black and brown were treated as follows:—No. 1, treated three times with ether to remove the grease. No. 2, boiled three times in water. No. 3, boiled with weak acid, then with water. No. 4, boiled with weak alkali, then with water. After drying, Fawsitt spread the rubber paste, and vulcanised two hours at 116° C. (240·8° F.). The coating thus formed was of no value, which condemned the theory, according to which the grease or the mordant remained in the stuff. It has been known for a long time that copper and its compounds exert a deleterious action on rubber. That opinion has been expressed by Thomson (*Indiarubber Journal*, 1891, p. 328), but in the case in question there was no copper. Fawsitt asked Mr. Christie, of the firm of J. Orr-Ewing & Co., a very competent chemist in regard to cotton-dyeing, if he could give an explanation of this fact. He thought that it might be due to the presence of peroxide of iron, and advised the testing of a piece of the buff cotton used so much for window blinds; this stuff was free from all foreign matter such as tannic acid and campeachy wood used in dyeing brown or black. His advice was followed, and it was found that the action of the vulcanising agent was retarded, which almost proved that the peroxide of iron was the sole cause of the failure; but if that were so, what was the reaction that took place? Although this was a special question, and almost inexplicable, the remedy was to allow its use on calico. This remedy consisted in first giving to the stuff a coating of pure indiarubber paste mixed with 2 per cent. of sulphur, a mixture often used in the ordinary dry heat process to prevent efflorescence. The study of the action of dyed fabrics on the indiarubber coating is important, not only for indiarubber

manufacturers, but also for dyers; and it seems that the solution of the problem ought not to be left to manufacturers, but submitted to the dyeing schools, who pay but little attention to this subject. Some rich indiarubber manufacturers would do well to encourage the study of these questions in technical schools. An important point is that by means of the new vulcanising agent a coating of coloured rubber may be easily obtained without the addition of a large quantity of pigment to the rubber. In the ordinary dry heat process it is difficult to obtain a good coloured coating, if only as much pigment be used as will enable the mixture to retain its elasticity. Coloured coatings are vulcanised in a period of time depending on the proportion of the vulcaniser and the material added, but the general time is from three-quarters of an hour between 116° and 118° C. (240·8° and 244·4° F.). The vulcaniser in question mixes very well with pigments, but some retard its action. It seems that the coatings obtained with it may be finished without farina, because the surface is dry and supple. This appears an argument in its favour, for farina seems to exert an injurious action on the surface of the rubber, because it is liable to become damp, and then ferment. But not only so, the moisture brings the farina to the surface of the garments, where it leaves aggravating spots. Fawsitt adds that the iodide employed by him in the manufacture of fishing stockings was antimony iodide chosen in preference to tin iodide on account of its cheapness and the good results obtained by its use. He also used tin iodide with good results; but, having started with antimony iodide, it was not afterwards thought worth while to change.

(2) *Modification of Parkes' process.*—Parkes' modified method consists in vulcanising a mixture of rubber and solid sulphur chloride:—Four pounds of rubber and six and a half pounds of solid sulphur chloride are simultaneously put through the mixer. The time required depends on the *speed* of the mixer, and the *weight* of the charge. It is therefore necessary from time to time to take samples and test if the elasticity be sufficiently developed. The mass is then taken out, compressed in a mould, whilst still hot, and afterwards washed. There is no advantage in this process, and the trade do not use it.

(3) *Humfrey's process* (British Patent, 3183; 1863).—The use of carbon disulphide, in the steeping process, is attended, from a hygienic point of view, with grave drawbacks, which it is important to remedy. Humfrey therefore proposes to replace carbon disulphide by another solvent, and, according to him, petroleum spirit replaces it both economically and hygienically. But the petroleum spirit must be perfectly anhydrous. To render it anhydrous, 60 to 80 kilos. (132 to 176 lb.) of petroleum are run into a vessel fitted with an agitator, and 10 per cent. of sulphuric acid of 168° Tw. sp. gr. 1·84 added; the mixture is stirred for some time, and then it is allowed to stand to allow the sulphuric acid to completely separate from the hydrocarbide. The petroleum is then transferred to another vessel by decantation, 200 to 250 grammes of quicklime per hectolitre (from 7 to 9 oz. per 22 gallons) are added, as well as a little manganese, and distilled. To test if the petroleum spirit is dehydrated enough to dissolve sulphur chloride, a small fragment of potassium is dipped into it, and after a few minutes, if the potassium diminishes in brilliancy, the petroleum is not dehydrated, and the potassium is covered with a layer of potassic hydrate. The function of the manganese is to absorb all traces of sulphurous acid which might be formed by the action of the sulphuric acid on the petroleum. Petroleum spirit is not without toxic effects, although perhaps not so dangerous as carbon disulphide. The abridgment of Humfrey's English specification will be better understood. In it no mention is made of quicklime; calcium chloride is the dehydrating agent specified: "Light spirit of petroleum dissolves indiarubber with great facility, but on evaporating this solution the deposited gum remains sticky, its elasticity is destroyed, and in other respects it is unfit for use. The cause of this appears to the inventor to be owing to the petroleum spirit being a hydrate, and, in order to deprive it of its water of hydration, 100 *gallons* of the spirit, sp. gr. 0·725, are mixed with 10 *gallons* of sulphuric acid, of a strength

not less than 1·840, and brought into contact by violent agitation; allowed to stand for some time, the acid drawn off by a stopcock from the bottom, the acid operation again repeated, and the spirit is drawn into a close vessel, avoiding exposing it to air, especially damp air; about 2 to 3 lb. of protoxide of lead and 1 lb. of peroxide of manganese in fine powder must then be added to 100 gallons of spirit, and the mixture must be well and repeatedly agitated. The spirit is fit for use, and will become bright by a few hours' resting." The patentee also rectifies the spirit by first agitating with and then distilling over calcium chloride. At the present day, however, the petroleum distillers sell a rectified deodorised petroleum spirit equally pure with any that could be prepared by the above process. It is not necessary for the manufacturer to multiply operations by becoming a petroleum spirit refiner and rectifier.

(4) *Gaultier de Glaubry's process.*—This process (similar to Parkes') consists in using, in place of sulphur chloride, a mixture of sulphur and hypochlorite of lime. The mixture soon heats and gives off sulphur chloride. If the mixture be now added to the rubber, vulcanisation goes on of its own accord, or by aid of a gentle heat; the results are the same as with Parkes' process.

(5) *Gerard's sodium polysulphide (liver of sulphur) process.*—It has been claimed for Gerard that he was the first to use alkaline sulphides, especially potassium penta-sulphide, in vulcanisation. But alkaline sulphides had been previously used by Charles Hancock in the preparation of gutta percha (British Patent, 11,874; 1847), and by Moulton in the vulcanisation of rubber (British Patent, 13,721; 1851). Moreover, Gerard did not (or could not) obtain a British patent for this purpose. He immersed the articles in a liver of sulphur of 25° Bé., and then baked them, under pressure, at 138° to 140° C. (280·4° to 284° F.). This process yielded excellent results; the rubber is vulcanised well and very regularly. When it is carefully washed its surface is smooth and soft and velvety, and does not afterwards give any alkaline reaction. Its great defect is that it is only applicable to small thin articles. On boiling, even under ordinary pressure, potassium sulphide destroys the tackiness of rubber. Liver of sulphur, 8 to 12 per cent. added to rubber, even in admixture with oxide of zinc, or carbonate of lime and quicklime, gives equally good results.

(6) *Gerard's alkaline process.*—By another process, Gerard prevents or greatly lessens the spontaneous decay of blocks of vulcanised rubber of certain size, a result which, with the preceding process, can only be effected in the case of thin articles. It consists essentially in mixing lime slightly slaked with the rubber, which, by its great fineness, can thus become incorporated with the interior of the mass. After sprinkling 100 parts of rubber with a mixture of 6 parts of sulphur and 6 to 10 parts of powdered lime, the ingredients are thoroughly mixed by passing the mixture through mixing rolls, heated between 45° and 50° C. (113° and 122° F.). The mass is then blocked, cut into sheets, and made into objects of any desired shape. Vulcanisation is effected in a closed vessel in a steam bath, at a temperature of 140° C. (284° F.). The operation lasts one and a half to three hours, according to the thickness. It then undergoes a kind of washing process, in which the surface loses some of its lime and sulphur. It is therefore less vulcanised, yet more supple, whilst, in ordinary processes, the superficial layer is vulcanised more strongly, and is thus harder and more brittle. The presence of lime in the sheet is opposed to the internal disengagement of sulphuretted hydrogen, and consequently to blowholes. Again, the rubber cannot assimilate an excess of sulphur, which combines, in preference with the lime, to form an alkaline earthy sulphide. Gerard called the rubber vulcanised by this method alkaline rubber, and claimed that the substance possesses all the properties of rubber vulcanised by Goodyear's and the potassium polysulphide processes, and is superior thereto by being more tenacious, from the fact that it can resist temperatures of 180° C. (356° F.) for several years without undergoing any change, a circumstance which enables it to be used in the making of boiler and steam-pipe joints.

(7) *Burke's antimony sulphide vulcanisation process.*—Antimony sulphide is,

certainly, the most important of all metallic sulphides suggested or tried. Experience has, moreover, consecrated it for certain special purposes. Hancock (British Patent, 11,575; 1847) recommended it, with other metallic sulphides, for the vulcanisation (*sic*) of gutta percha, and W. Burke (British Patent, 12,591; 1849) for the vulcanisation of waterproof fabrics. Burke used precipitated antimony sulphide, made as follows:—To 1 part of crude antimony sulphide 25 parts of crystallised sodium carbonate or 20 parts of potassium carbonate dissolved in 250 parts of water are added; the whole is boiled in an iron pan for thirty to forty-five minutes, after which the undissolved materials are allowed to settle. The solution is filtered whilst still hot, and the potash or soda is neutralised by hydrochloric acid, in slight excess. There is thus obtained a bulky precipitate of orange red antimony sulphide (*Kermes*), which, washed to free it from hydrochloric acid, is dried very gently to expel moisture. Five to fifteen per cent. of *Kermes* is mixed along with the rubber, according to the required degree of elasticity, then vulcanisation is proceeded with at a temperature of 126° to 137° C. (258·8° to 278·6° F.). Rubber so prepared has a brown colour; it excels not only in strength and elasticity, but also in the faculty of resisting the influence of the solar rays, and of preserving its softness and flexibility at a low temperature—essential qualities for garments. It has the further property of not producing an efflorescence afterwards on the surface of vulcanised articles, and contact with metals is less injurious to it than to other vulcanised rubbers.

(8) *Moulton's lead sulphide process.*—To this class of processes belongs that described in British Patent, 11,567; 1847 (Moulton)—vulcanisation by sulphide of lead. Moulton employed lead sulphide for elastic articles, or mixed with magnesium carbonate for harder articles of greater tenacity. This same inventor (British Patent, 13,721; 1851) likewise recommends a mixture of sulphide of lead, or zinc sulphide with salts of lead and zinc. Vulcanisation by lead and zinc sulphides appeared to Moulton to impart great flexibility to rubber, without inducing any efflorescence. It is the same with the *mercuric sulphide* process; but the high price of mercury prevents its use, except where vermilion fulfils the rôle of both vulcanising agent and colouring principle, but otherwise it gives good results (British Patent, 1218; 1864, Bateman: and 2541; 1866, Forster).

(9) *Turner's process* is based on the simultaneous employment of the sulphides of bismuth and lead (melting 5 lb. of bismuth and 5 lb. of lead, to the fused alloy of which 5 lb. of sulphur are added). The pulverised mass is mixed in the proportion of 1 part with 3 parts of rubber, and vulcanisation is effected at a temperature of 138° to 142° C. (280·4° to 287·6° F.). It is claimed for rubber so vulcanised that it stands heat well. According to Turner (British Patent, 305; 1866), it would support 200° C. (392° F.) without either hardening or becoming brittle. But test experiments by Heinzerling have not confirmed these predictions.

(10) *Schwanitz's glycerine vulcanisation process.*—This is only a slight modification of Goodyear's. It consists in adding a certain dose of glycerine, and heating in a glycerine bath. According to the inventor, rubber so vulcanised stands the actions of oils and fats well, without losing any of its other qualities. The glycerine is incorporated by itself, or a mixture of glycerine and solid bodies, such as oxide of zinc, chalk, flowers of sulphur. The inventor specially recommends the following mixture:—

TABLE XXXIV.—SHOWING INGREDIENTS OF MIXTURE FOR CURING RUBBER BY SCHWANITZ GLYCERINE PROCESS.

	Parts.
Indiarubber	3·0
Chalk	3·0
Glycerine	0·5
Flowers of sulphur	0·1

Articles manufactured from this mixture are heated for about two hours in an autoclave at a pressure of about 2 atmospheres. The duration of the heating depends on the thickness of the sheets. Treatment with pure glycerine should suffice, according to Schwanitz, in the majority of cases, *e.g.* to render the rubber unattackable by oils and fats. One is at a loss to understand how glycerine by itself is capable of imparting this property to rubber. Its action in presence of litharge, with which glycerine forms a very solid resistant mastic, is readily understood.[1]

(11) The *metallisation process* of the Franco-American Company, whereby vulcanisation is effected (according to the *Moniteur Industriel*, 1880, vol. vii. p. 64) by the intervention of lead or antimony in impalpable powder may also be mentioned, but a decision as to the value of this process, or the special methods by which this mixture is applied, cannot be arrived at for want of the necessary data.

(12) The same remark applies to the vulcanisation process suggested by *Balard*, in which sulphur chloride is replaced by sulphur bromide, the process not yielding any marked advantage over the chloride.

(13) Finally, the process of Moureley, of Manchester (1884), which has the undoubted advantage of not leaving in the rubber any ulterior effect from free sulphur, may be recalled. It consists in vulcanising rubber with 2 to 3 per cent. of sulphur in ammoniacal solution of 12 per cent. strength, or in the midst of ammoniacal vapours.

Vulcanisation properly so called—Definition—Influence of temperature.—Vulcanisation is the result of the heating of rubber, intimately mixed with sulphur or its derivatives, in a stove or by superheated steam. The most favourable temperature for vulcanisation is from 120° to 136° C. (248° to 276·8° F.). The opinion according to which vulcanisation takes place at 110° C. (230° F.) is erroneous. Heinzerling proved, by a series of direct experiments, that when rubber is submitted to a temperature of 100° C. (212° F.) for four or five hours, there is no trace of vulcanisation. For vulcanisation to take place, the melting-point of sulphur, namely, 113° C. (235·4° F.) must always be exceeded. The selection of the right heat for vulcanisation, according to circumstances, constitutes the most delicate point of this operation. Too great a heat scorches the material, which thus loses its elasticity, and quickly becomes brittle, especially on the surface; with too low a heat vulcanisation is only superficial, and does not reach the heart of the object.

Test for differentiating between perfectly and imperfectly vulcanised rubber.—A characteristic sign by which an incompletely vulcanised rubber may be recognised is to draw it out at a gentle heat; if completely vulcanised, the rubber easily reassumes its primitive form; if not, it remains partially stretched. If a strong pressure be exerted on incompletely vulcanised rubber, a permanent hollow is formed.

Length of time required for perfect vulcanisation.—The time required for complete vulcanisation depends on — 1. The quality of the rubber, *e.g.*, Para rubber vulcanises more slowly than soft, sticky East Indian sorts. 2. The cross-section of sheet to be vulcanised. Thin articles are vulcanised within the first hour; thicker objects require two to three hours.

Stoves.—Hot-air masonry stoves were formerly used, the wrought sheet-iron bottom of which received the direct heat of the flame by means of flues arranged *ad hoc*. The objects to be vulcanised were placed in the stove and kept at a certain distance from the bottom by means of special hanging lines, either horizontal or vertical, so as to receive the heat equally all over. These stoves are no longer used, except in special cases, in the manufacture of varnished indiarubber shoes and certain garments termed stove-vulcanised. But in vulcanising by hot air the presence of litharge in the vulcanising matter is indispensable; without this body no vulcanisation takes place. These stoves are at the present day replaced

[1] Glycerine may neutralise the free fatty acids in the nascent state, and thus prevent them from accumulating and acting on the rubber.—Tr.

by superheated water or steam vulcanisers. The use of steam under pressure enables the temperature to be regulated more easily than by hot air.—*Steam vulcanisers.*—As a steam bath there was formerly used an apparatus in which rubber was vulcanised, whilst at the same time steam was generated therein. These boilers are now replaced by special apparatus in connection with a steam boiler. The pressure is regulated by a valve, which is controlled by a manometer on the outside of the vulcaniser. Before describing a vulcaniser of this kind, it will be useful to give a table of the tensions of steam at different temperatures between 100° and 150° C.

TABLE XXXV.—SHOWING THE TENSION OF STEAM AT DIFFERENT TEMPERATURES.

Temperature.		Tension of the Steam in Millimetres of Mercury.	Tension in Atmospheres.[1]
°C.	°F.		
100	212	760·000	1·00
105	221	906·410	1·19
110	230	1075·370	1·41
115	239	1269·410	1·69
120	248	1491·280	1·96
125	257	1748·880	2·28
130	266	2030·280	2·67
135	275	2353·730	3·08
140	284	2717·630	3·57
145	293	3125·550	4·11
150	302	3581·230	4·71

Karmarsch and Heeren's vulcaniser.—The vulcaniser illustrated in Fig. 69 is made of very strong wrought-iron. It is often 14 to 20 metres (say 45 to 65 feet) long,

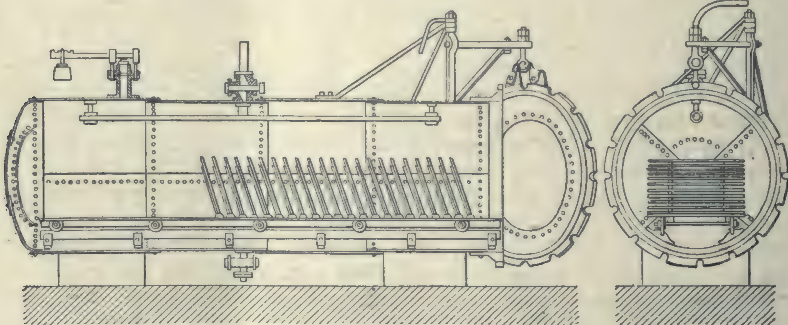


FIG. 69.—Karmarsch and Heeren's vulcaniser.

which enables comparatively large-sized pieces to be treated. To prevent india-rubber tubes being deformed in vulcanising, they are mounted on an iron mandrel, the diameter of which corresponds with the inside bore of the tubes. This vulcaniser is 50 to 65 feet long, with a diameter of 16 to 20 feet. Its construction is identical with an ordinary steam boiler. The body of the cylinder is provided at its open end with a cast-iron flange, fitting an identical projection on the lid, so as to form an autoclave. Sometimes the projection of the door fits into a groove made round the body of the cylinder, and, so that closing may be perfect, half filled by packing

[1] The pressure in lb. per square inch may be approximately got by multiplying the atmospheric tension by 15.

consisting of 25 parts of tow and 75 parts of supple alkaline rubber. The lid fits into this projection by means of collars, clasps, hinges, and bolts. Moreover, it can be moved by fixed tackle, or a small crane which facilitates its manipulation, so

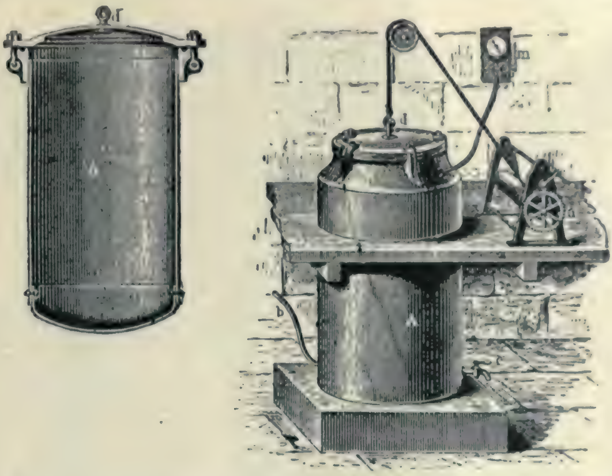


FIG. 70.—Apparatus for vulcanising small objects by high-pressure steam.

that it can either be taken away from or brought back and fitted to the mouth of the cylinder. To facilitate the introduction of the articles to be vulcanised, a tramway is laid down on the bottom of the boiler, on which moves the small waggons, mounted on wheels, and fitted up to receive the objects to be vulcanised,

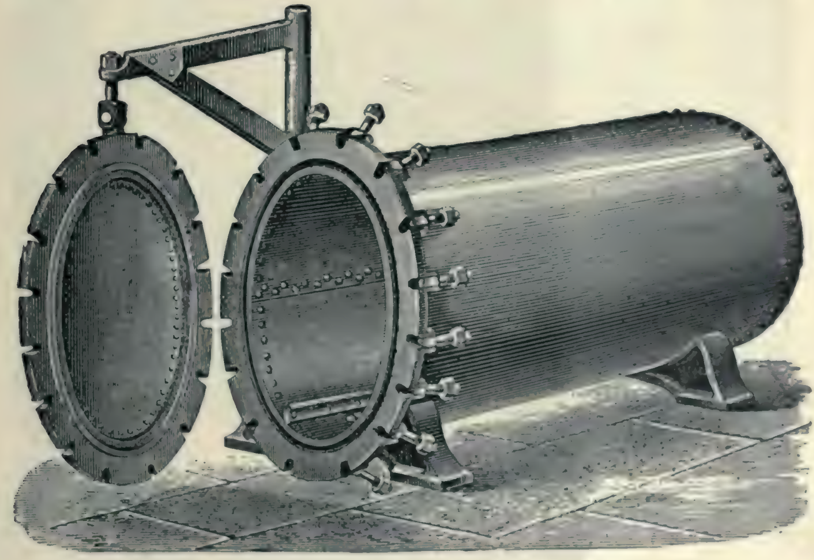


FIG. 71.—Coster, Rickkers, & Co.'s steam vulcaniser.

either laid on the flat or hung up as occasion may require. A steam pipe, fitted with a stopcock, spreads the steam uniformly throughout. It goes right along the upper part of the cylinder, and its lower part is perforated by an infinite number

of small holes. The cylinder is surmounted by a safety valve, and a blow-off cock for either air or condensed water is fixed to the lower part. The inside of the boiler is furnished with a number of hollow cylinders, provided with springs and

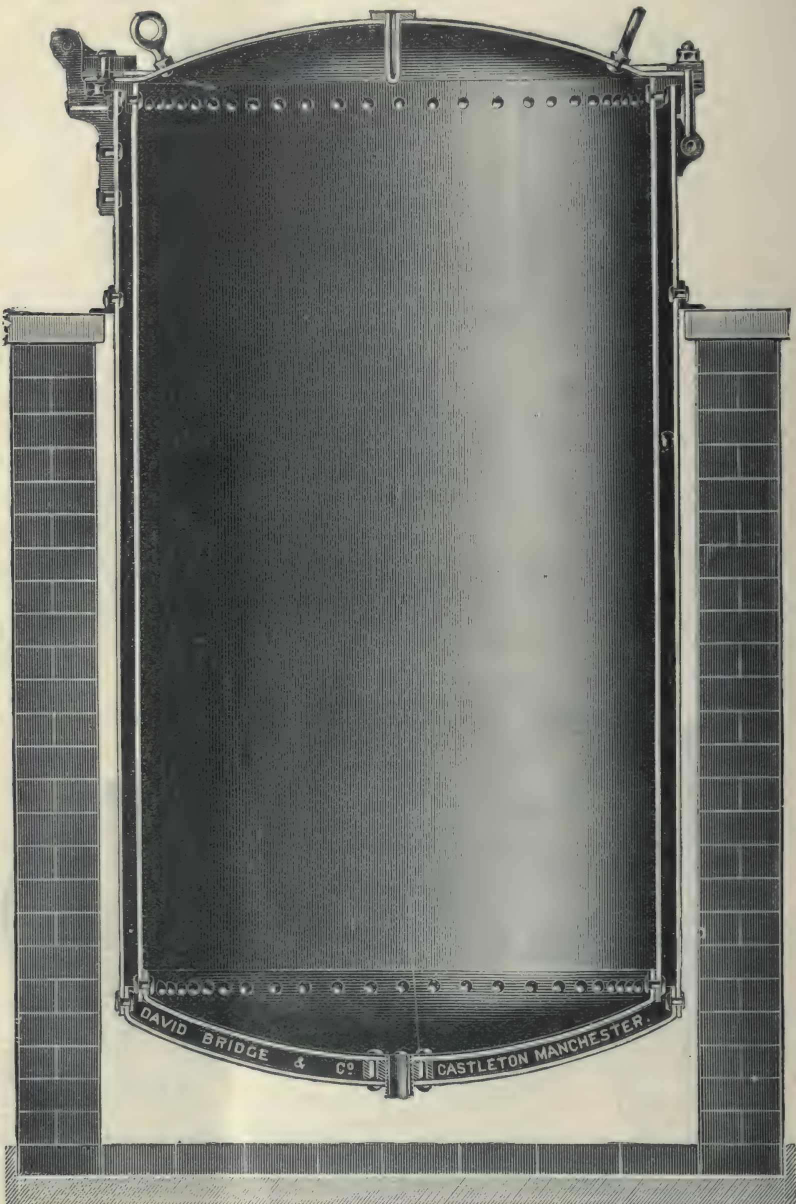


Fig. 72.—Vertical steam-cased vulcanisation pan.

supports intended to keep the laminated sheets entabled on the wrought-iron plates. The interior arrangement may vary from one factory to another, according to particular requirements of special branches of the industry.

Vulcaniser for small objects by high-pressure steam.—Fig. 70 shows another

form of vulcanising boiler, used especially for small objects, and for vulcanising by means of water heated by high-pressure steam. It is 60 to 65 inches in diameter and from 16 to 20 feet in length.

The boiler *A* may be horizontal or vertical. If vertical, it is provided with an arrangement for taking off and putting on the lid *d*. If horizontal, this lid can be manipulated at will by a similar arrangement. In that case a waggon moving on rails is installed in the boiler to support the objects to be vulcanised enclosed in

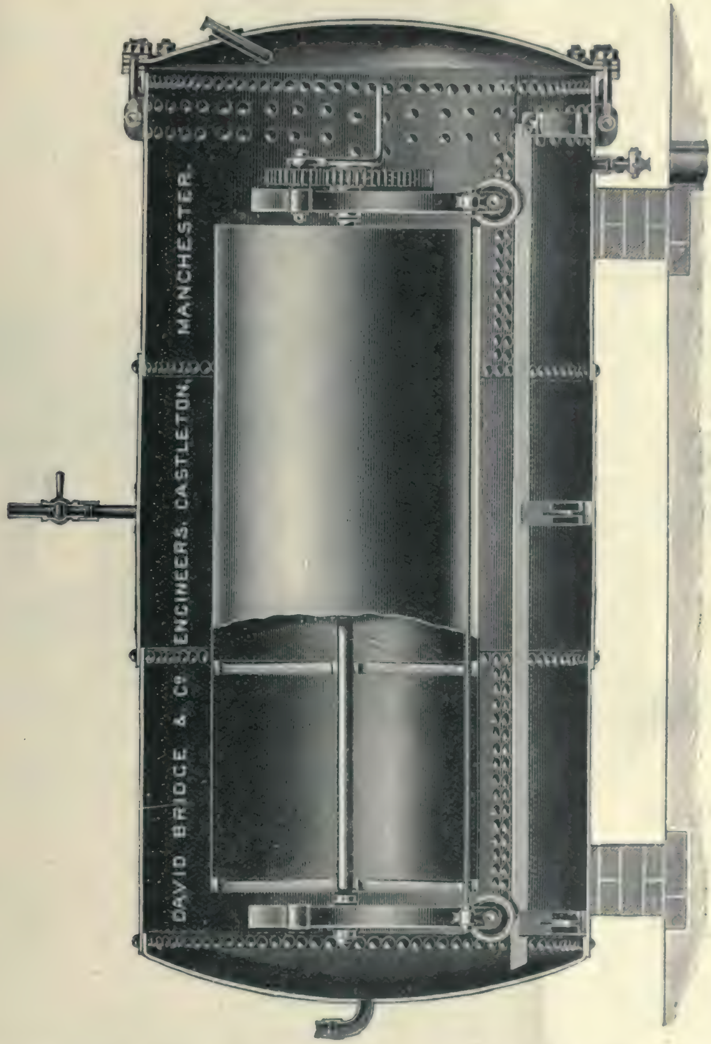


FIG. 73.—Horizontal open type pan, with cloth cylinder for vulcanisation

their iron moulds. The pipe *b* communicates with the steam boiler. The pressure in the interior of the vulcaniser is regulated by a valve; *m* shows the manometer (steam gauge), and *e* the blow-off cock.

Hot-water vulcanisers.—These are similar to steam vulcanisers, only they are fixed in a vertical position and contain water up to a certain level. The steam reaches the vulcaniser, raises the temperature of the water from 125° to 130° C. (257° to 266° F.), and vulcanises the articles dipping into it.

Rickkers' steam vulcaniser.—This is shown in Fig. 71. By fixing it vertically

and suppressing the rails, it can likewise be used for vulcanising with hot water.

Steam-jacketed pans as vulcanisers.—Double-bottomed vessels (steam-jacketed pans) may also be used in vulcanising. The steam is introduced between the two cylinders, and heats by radiation the air contained in the inside cylinder, and consequently dry vulcanises the objects it contains.

Vulcanising press or vulcanisation by contact.—It is an advantage in a rather large establishment to have a small vulcaniser in which to perform, without any great expense, experiments on the vulcanisation of certain rubbers or of certain mixtures. These small utensils are called *monkeys* (marmots). For this kind of work (1) screw presses, (2) screw presses with hinged levers, and (3) hydraulic presses, etc., are used.

1. *Screw presses.*—The apparatus is arranged like a letter-copying press. They consist of two hollow plates, heated in the interior by steam. The lower plate is fixed, and rests on a table or support. The upper plate is raised and lowered by

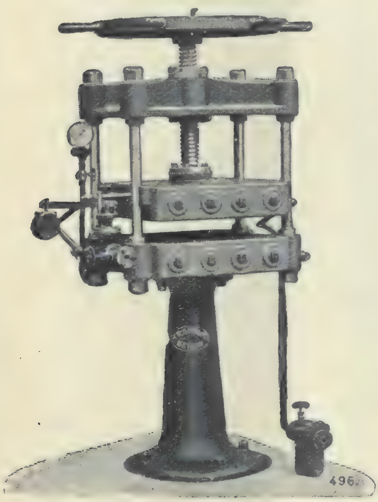


FIG. 74.—Single-screw vulcanising press with all accessories. Plates, 600 by 600 millimetres.

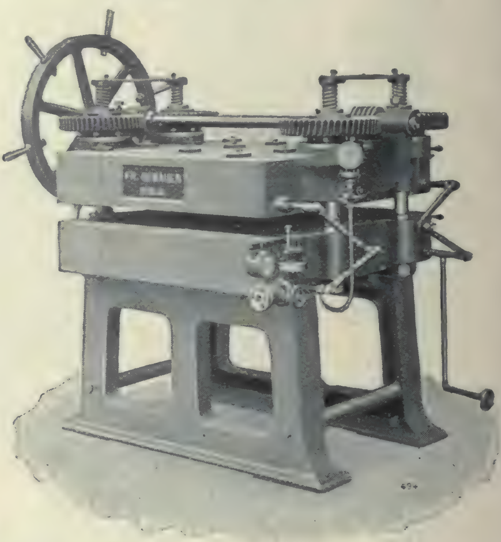


FIG. 75.—Hand power vulcanising press. Plates, 1250 by 1250 millimetres (say 50 by 50 inches).

means of a male screw turning in a fixed female screw, drilled out of the cross-piece. It is guided in its movements by the lateral columns. A manometer or steam-pressure gauge communicates with one of the plates, so that the steam pressure may be ascertained and regulated by a valve fixed on the steam arrival pipes. Articles made of mixed rubber are placed in moulds between the two plates of the press, which are strongly compressed. The length of time taken varies; generally matters are so arranged that, with a pressure of between $2\frac{1}{2}$ and 4 atmospheres, vulcanisation is complete in two hours at the furthest. The time taken is often reduced to an hour, and even to half an hour. All depends on the proportion of the sulphur, the steam pressure in the plates, and the nature of the mixture. The two organs being suitably proportioned, single-screw presses are constructed, with plate, 1 metre (say 3 feet 3 inches) to $1\frac{1}{4}$ metres (say 4 feet) square. The largest-sized presses have plates which measure 3 to 4 metres (say 10 to 13 feet) in length, with a width of 1 to $1\frac{1}{2}$ metre (say 3 feet 3 inches to 5 feet). These machines are provided with two or three pressure screws. So that the upper plate may descend regularly and bear uniformly throughout all its

length, all the screws should act conjointly. Each screw carries on its upper part a toothed wheel of the same diameter. Each of these wheels gears with a corre-

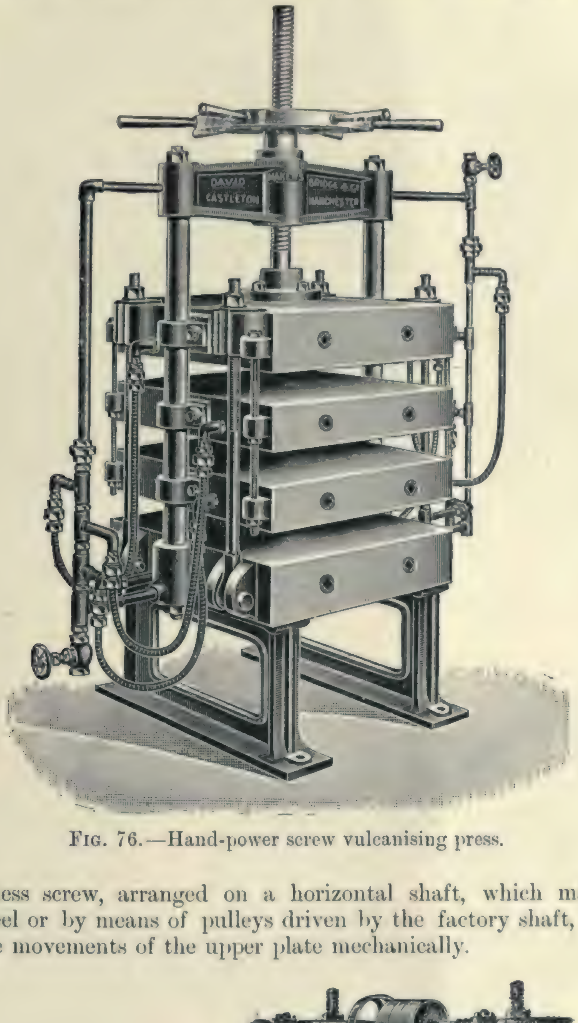


FIG. 76.—Hand-power screw vulcanising press.

sponding endless screw, arranged on a horizontal shaft, which may be driven from a fly-wheel or by means of pulleys driven by the factory shaft, which in that case works the movements of the upper plate mechanically.

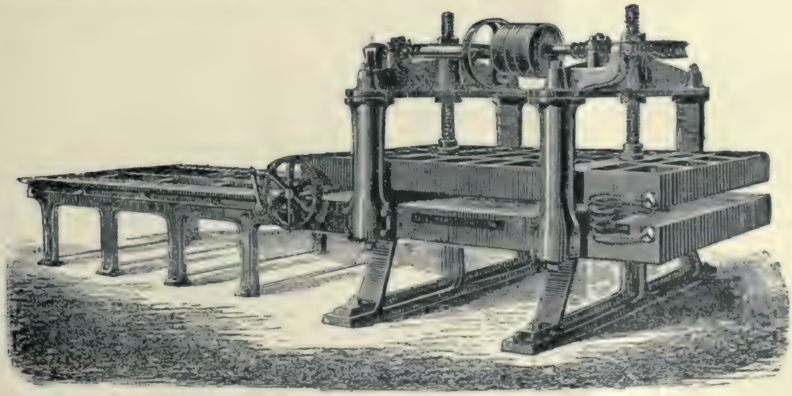


FIG. 77.—Vulcanising press—double-screw—Leblanc system.

1*a*. *Leblanc's double-screw vulcanising press.*—This press is shown in Fig. 77, and is of the two-screw type (Leblanc's construction). The upper plate is wrought mechanically. It is 3 metres (say 10 feet) in length and 4 metres (say 13 feet) in width, which dimensions enable it to be used for vulcanising indiarubber belts and sheeting.

2. *The screw press with hinged levers* is less common, although it does good work.

Mongin's three-plate vulcanising press.—This press consists of a horizontal screw, the one half with a left thread, the other half with a right thread; four-hinged levers; two hollow plates, and a suitable frame. Two levers are hinged, on the one hand, to a first female screw which surrounds the male screw; and, on the other hand, one to the movable plate and the other to the fixed head of the press. The two other levers are arranged in the same way in relation to a second female screw on the other part of the male screw. By working with a fly-wheel, gearing

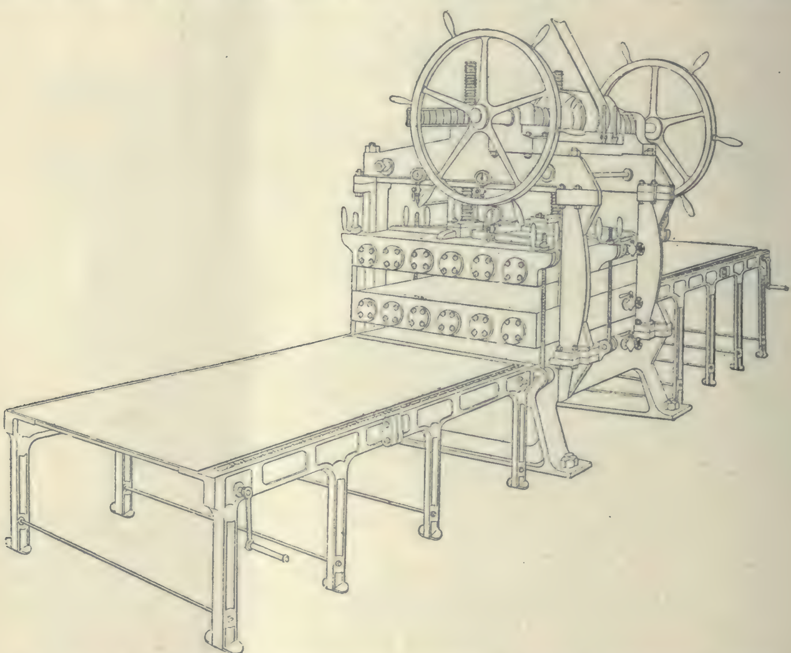


FIG. 78.—Vulcanising screw press with three plates—Mongin's strengthened system.

on to the horizontal screw, the female screws approach, or cause by means of the levers raise or lower the suitably guided movable plate. The hollow plates are heated by steam, and the articles arranged in moulds are compressed between the plates as in the ordinary screw press.

Press with cylindrical guide.—Coster, Rickkers, & Co. construct cylindrical guide screw presses of a particular pattern. The screw, wrought by a shock fly-wheel, acts on the upper cast-iron plate with a cylindrical, vertical, mobile body placed inside another fixed cylinder. The plates thus remain quite parallel, and the pressure is very uniform.

3. *Hydraulic press.*—In the hydraulic press the motion of the plate is obtained by water pressure and by the intermediary of accumulators. The two plates are heated in the ordinary way, and compress the articles introduced into the moulds. This class of press is used more especially to vulcanise transmission belts. The plates then often reach 4 to 5 metres (say 13 to $16\frac{1}{2}$ feet) in length, and 1 to $1\frac{1}{4}$ metre (say 3 feet 3 inches to 4 feet) in width. A three "nip" hydraulic press is

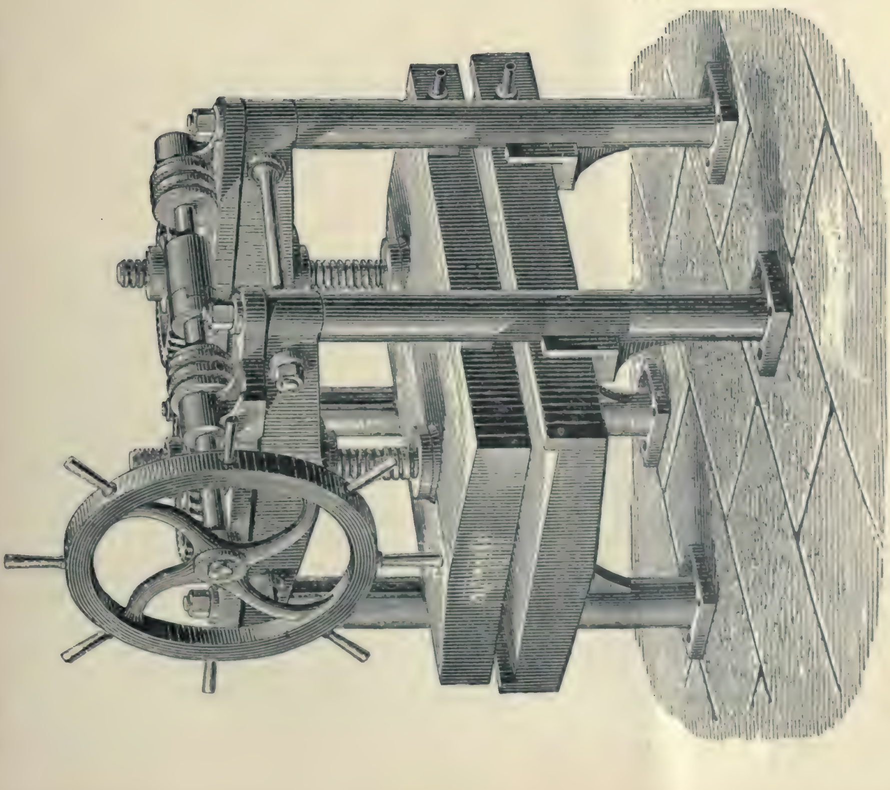


FIG. 79.—Vulcanising press with cylindrical guide—Coster, Rickkers, & Co.'s system.

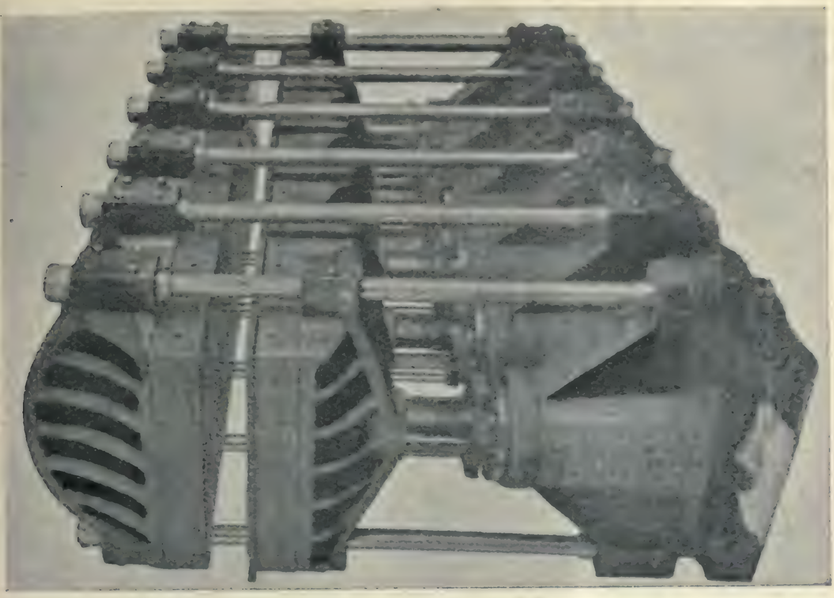
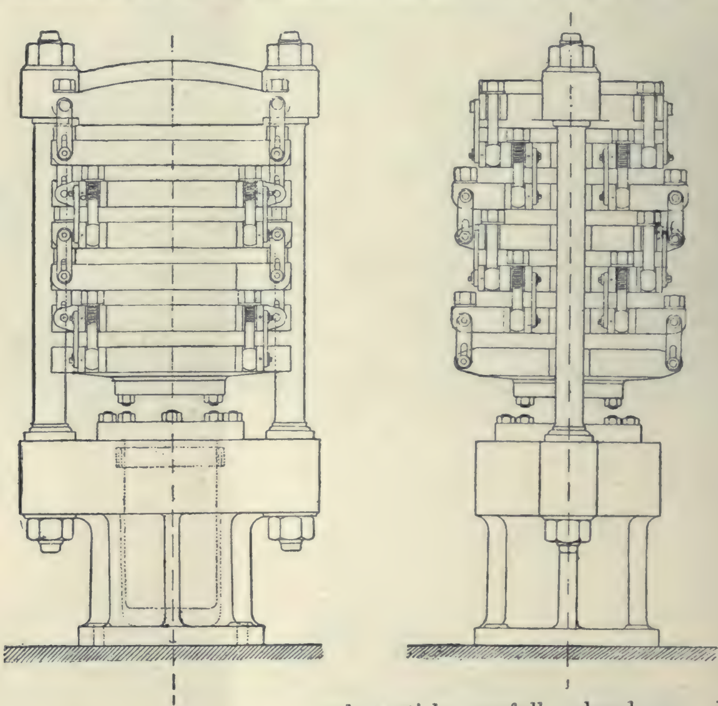


FIG. 80.—Hydraulic press with six pistons for vulcanising belts—Birmingham Iron Foundry system (U.S.A.).

shown in Fig. 81. The plates are guided by four uprights. Fig. 80 shows a hydraulic press for belts, driven by six pistons. The powerful machines are also made by the Birmingham Iron Foundry.

Vulcanisation of hollow articles.—Hollow articles, such as balloons, dolls, etc., are first of all put together and "soldered," then a small quantity of volatile liquid, without action on the substance (water, ammonia, etc.), is introduced, and



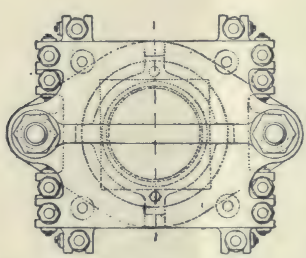


Fig. 81.—Plan of hydraulic vulcanising press with six plates —Mongin's system.

the article carefully closed up. In this state they are heated and vulcanised in moulds of one or more pieces. When the heat begins to act, the water is converted into vapour of a certain tension, the ammonia is volatilised, and the gases thus generated exert sufficient pressure to push the pellicle of rubber against the sides of the mould, which impresses itself to the very minutest details on the sheet of hollow rubber. In addition to these machines, each factory may design and construct appropriate machines, based on the same principle of vulcanisation, for each special article of manufacture, such as the hollow rings, the envelopes for pneumatics (air and gas vessels and appliances, bicycle and motor car tyres), etc.

Decauville's vulcanising presses are fitted with hollow plates, in the interior of which steam circulates, and the presses may be either one "nip" or two "nip"; each hollow plate has three unions, one for steam inlet, a second for steam exit, and a third for the pressure gauge.

Preserving the initial form of manufactured rubber during vulcanisation.—During vulcanisation, whatever may be the shape of the rubber, it will soften, under the influence of heat, so as to warp or assume the imprints of the supports which keep it in position, if care be not taken to ensure the preservation of the

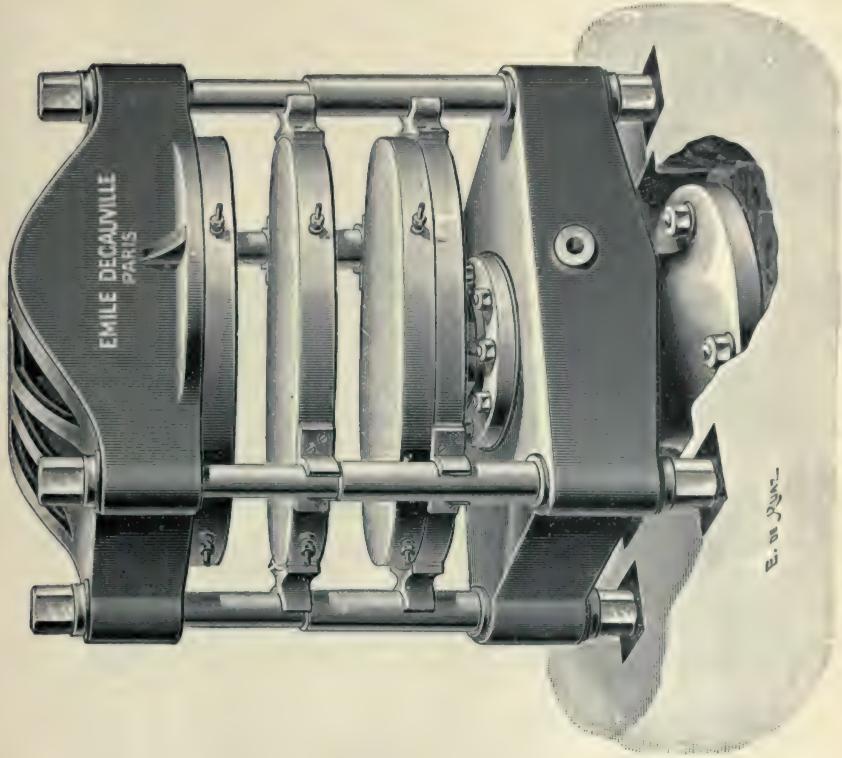


FIG. 83.—Hydraulic vulcanising press (Decauville, Paris).

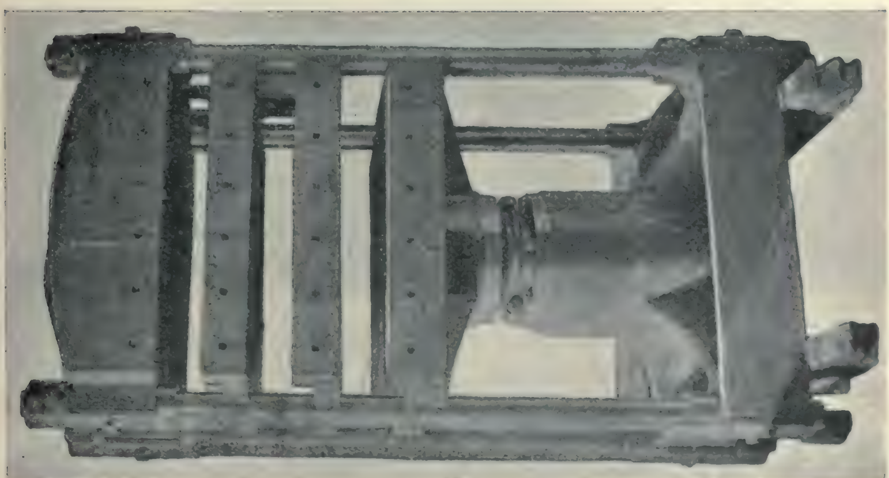


FIG. 82.—Hydraulic vulcanising press three plates—Birmingham Iron Foundry (U.S.A.).

shape by suitable packing. Tubes are vulcanised on mandrels, which sufficiently preserve their shape. Cushions, rings, and articles are enclosed in special iron moulds. Solid articles are placed in sheet-iron cases lined with talc, sheets of a certain size between sheet-iron, and thin sheets rolled on a drum with calico linings.

Blowholes and their remedy.—During vulcanisation a defect often occurs, as difficult to avoid as to explain, namely, blowholes which form on the surface of technical articles, or which in lined articles (caoutchouc and canvas) even sever the two substances. The trade market refuses articles of this kind. Experience shows that, where these blowholes occur, a rupture is always to be feared in time. They

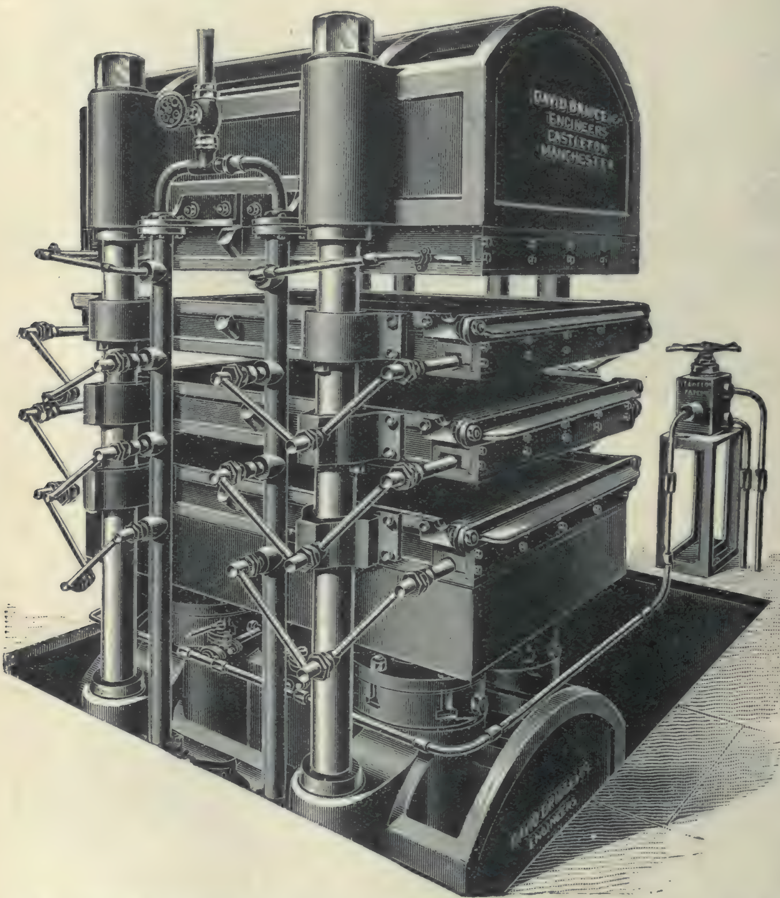


FIG. 84.—Three "nip" hydraulic press for vulcanising rubber sheets 6 ft. 4in. by 4 ft. 4 in.

are due to the use of imperfectly dried rubber or to incomplete evaporation of the solvent in lined articles. The preparatory mechanical working of too fresh rubber, and more especially the compression exerted on the mass by the tools, collect the interstitial water into small vesicles, which, under the influence of heat, become converted into steam, and thus form the bells on the spots where they occur. The substance often becomes quite porous, not only on the exterior, but also in the interior. It is recommended to remedy this first drawback by adding from $\frac{1}{2}$ to 1 per cent. of quicklime, so as to absorb, in the mixer, all the interstitial moisture, experience having proved that, after this addition, the wrought rubber only very rarely showed this defect. As to separation, this especially occurs in

lined articles, made by the interposition of a solution of rubber between the sheets of cloth, and not in the case of laminated sheets, and it is the solvent, carbon disulphide, benzol, etc., which so acts as to prevent adherence. Certain experts think that it is due to sulphurous acid generated during vulcanisation. This is not so, and oxide of lead added to absorb sulphurous acid never prevented blow-holes from being formed. Attention has already been drawn to the action of

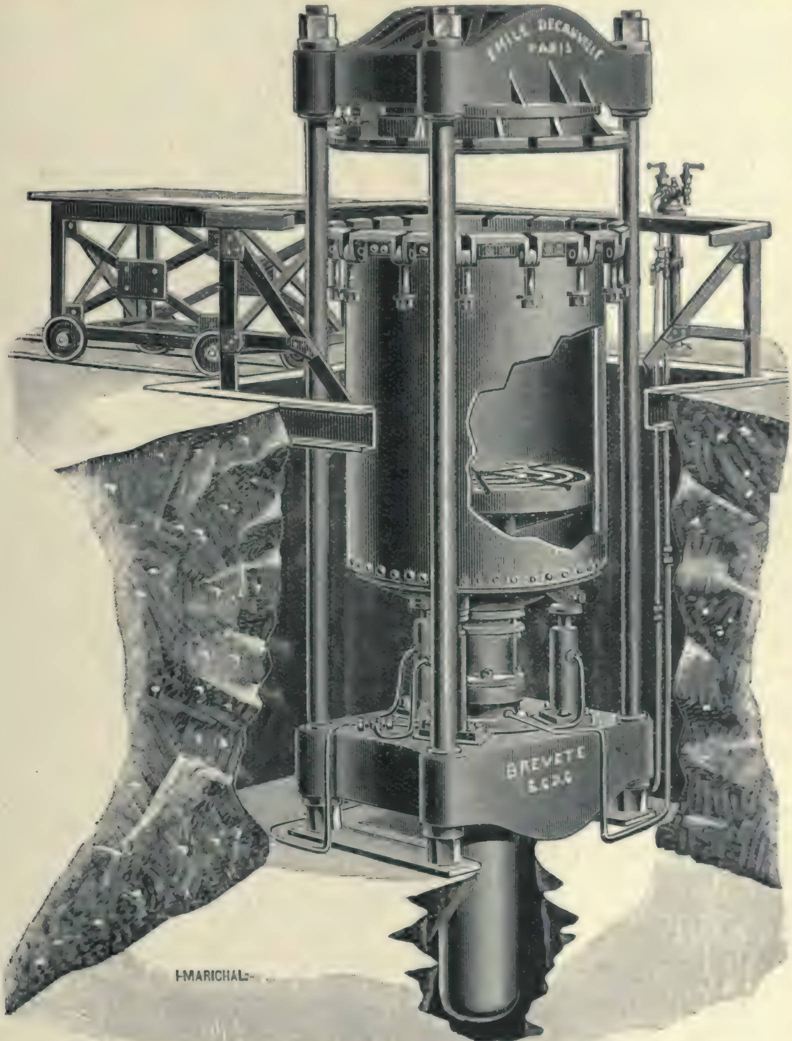


FIG. 85.—Hydraulic vulcanising autoclave (Decauville, Paris).

impurities, and of oxidised rubber upon sulphur, and it is possible that the gases generated by such reactions aid the formation of these blowholes.

Hydraulic autoclave presses—Description.—The numerous advantages of vulcanisation in closed vessels have led to the study of new types of hydraulic presses combining the principle of the autoclave. The autoclave is cylindrical, and consists of an iron plate rivetted to a flange or collar and a bottom of cast steel. It is fixed to the lid by means of the collar, and is closed by nuts and screw bolts.

The cast-steel bottom of the autoclave carries a stuffing-box in which the piston of the press glides. The moulds placed on the plate are therefore, whilst subjected to hydraulic pressure, in an absolutely closed space, and are thus brought to a strictly uniform temperature. This autoclave moves in a vertical direction by three hydraulic methods of working. When it is about to be charged the autoclave is lowered by means of the three hydraulic methods, then the piston of the press is caused to ascend and consequently the plate in such a way that the latter is level with the upper part of the autoclave. It is charged with moulds, and the piston lowered gradually to a height equal to that of the moulds on the plate. Once charged the autoclave is raised by means of the screwjack of the press. All that has to be done now is to turn on steam on to the autoclave. During the operation the autoclave rests on the screwjack in constant communication with the accumulator, consequently the expansion of the autoclave occurs freely. When by inadvertence the communication between the screwjack and the accumulator are obstructed, Belleville washers, placed between the bottom of the autoclave and the top of the pistons, will give sufficient play for this expansion. The usual dimensions are—power, 70 tons; hydraulic pressure, per square centimetre, 100 kilos.; diameter of the plate, 1·2 metre; course of the piston, 1·2 metre; useful space in height, 1·5 metre; approximate weight, 9 tons. The autoclave is fitted with three adjustments, namely, steam injection, steam exit, and pressure gauge.

Theoretical review of vulcanisation.—The effects of vulcanisation are due to ill-defined causes, as yet hardly understood. The chemical reactions which occur in the process have hardly been studied, far less satisfactorily explained. Authorities are all more or less undecided. They describe vulcanisation as the result of an "absorption" of sulphur, but omit to state exactly what they mean thereby. They acknowledge that the rubber absorbs 2 per cent. of sulphur, but they do not agree as to the nature of that absorption. Some state that vulcanisation is the result of a real chemical reaction, commencing at 120° C. (248° F.) and terminating at 160° C. (320° F.). Vulcanisation properly so called, *i.e.* the transformation of normal rubber *into a rubber which is pliant and elastic in all temperatures*, would be the starting-point of this reaction, and the production of *hardened rubber*, *ebonite*, the final result. 1. *Payen* sums up the reactions which occur as follows:—"As soon as the sulphur commences to react, and during the whole process, *i.e.* between 135° C. (275° F.) and 145° C. (293° F.), combination of sulphur with a small quantity of the hydrogen of the organic body takes place, and there is thus a continual formation of sulphuretted hydrogen, of which the sulphur may absorb as much as its own volume; hence a peculiar phenomenon results in working with the bath process: when the temperature lowers after vulcanisation, the sulphur in crystallising liberates a portion of sulphuretted hydrogen. This gas is disengaged between the crystals, and rises up the semi-fluid mass. The converse occurs, and contraction is manifested during the cooling, and the sulphur crystallises exempt from sulphuretted hydrogen." Payen, having examined a sheet of rubber vulcanised by the bath process, found that the sulphur *combined* with the rubber was unequally distributed in gradually decreasing proportions from the interior of the pores to the dense portion of the organic substance. "Thus," says he, "there can be perceived, under the microscope, concentric circles indicating this decrease, and we can extract in rotation, by appropriate solvents, carbon disulphide, ether, etc., 4 per cent. of caoutchouc, 1 to 1·5 per cent. of fatty matter, besides the free sulphur." Payen's theory, supported by arguments developed above, is not conclusive. Disengagement of sulphuretted hydrogen might proceed from a small quantity of rubber decomposed by sudden immersion in sulphur at the high temperature of its melting-point, otherwise the disengagement would not cease, even after the goods, vulcanised by steeping, had been sufficiently washed with an alkaline solution, which is not the case. The latter remark of Payen is, moreover, in contradiction with the first, and indicates at least that chemical combination, if it does exist, is only partial, since the *combined* sulphur is unequally distributed in decreasing proportions from the interior of the pores to the dense portion of the

organic matter. 2. *Heinzerling*, for different reasons, and in a much less affirmative manner, believes also in real chemical combination. "We do not yet know, really, whether sulphur, in combining chemically with rubber, forms a simple juxtaposition of an addition product or if it substitutes itself partially for hydrogen. *That the combination of sulphur with rubber forms a real chemical compound would appear to be the undoubted result of the fact that rubber and sulphur, both soluble in carbon disulphide before being exposed to heat, are insoluble therein afterwards.*" The proof seems a decided one, and yet, metallic sulphides, like antimony sulphide, are throughout an excellent means of vulcanisation, but are in no way soluble in carbon disulphide. This also is the case with the sulphides of mercury and lead. Yet two metals may have isolately certain properties which disappear completely when they are united, not by a simple mixture but through the intervention of heat, through alloying, which very often gives them diametrically opposite properties. 3. *Unger* agrees up to a certain point with Heinzerling, but for different reasons. "We do not know," says he, "the nature of the organic sulphur compound formed by vulcanisation; *it might be possible* that the white coating formed on the surface of the large lumps of rubber, which appears under the microscope as small brilliant crystals, consists of sulphur and hydrocarbide, and that it is this compound which, spread throughout the mass, communicates to it the properties of vulcanised rubber." It has now been proved that this efflorescence is no other than crystallised sulphur, and that the contraction of the cooled globulites push it to the surface of the indiarubber. 4. *Vulcanisation explained by the action of presence.*—Certain authors try to explain the effects of vulcanisation by the theory of juxtaposition, by the action of presence, "catalysis." This theory is simple and easily formulated, but it proves absolutely nothing, and is in flagrant contradiction with facts. The action of presence might in case of necessity justify the increased suppleness, the greater elasticity of the rubber; but how, then, can the absolute insolubility of the really vulcanised rubber in carbon disulphide be explained? How can a greater resistance to chemical reagents be explained? How is the transformation of vulcanised rubber into ebonite, by an elevation of temperature, a prolongation of the process, and an increase of the sulphur, to be interpreted? How, finally, in vulcanisation by steeping, can there be disengagement of hydrochloric acid according to this theory? 5. *Vulcanisation an indefinite combination as in alloys.*—A certain number of chemists—*e.g.* Donath—consider vulcanisation, not as a phenomenon of a purely chemical order, resolving itself into combination in definite proportions, but the formation of molecular combinations in indefinite proportions, as is supposed to occur with certain series of alloys. They urge against combination in definite proportions the objection that vulcanisation is produced equally well with a metallic sulphide as with free sulphur. How, then, can the sulphides of antimony, mercury, or lead abandon the whole of their sulphur to some complex rubber compound? Unvulcanised rubber hardens at moderately low temperatures, whilst it softens and loses its elasticity when it is heated between 50° C. and 60° C. (122° F. and 140° F.), and, moreover, its resistance towards reagents is feeble. But vulcanised rubber preserves its elasticity both in the heat and in the cold, resists chemical reagents better, and behaves altogether differently towards solvents and reagents. These properties recall those of alloys, whose behaviour is so often dissimilar to that of their components, even when one exists only in but relatively minimum proportions.

Vulcanised rubber may therefore be regarded as a sort of alloy of the organic substance of the rubber with sulphur or with a sulphide, or even with sulphur chloride, bromide, or iodide. This condition is not combination properly so-called, from which the formation of a well-defined chemical individuality would result; it differs, however, from simple solution or mechanical mixture.—Neither of these three explanations of vulcanisation is satisfactory, if taken individually, and their collection into a well co-ordinated single aggregate would at the most be capable of giving a barely plausible theory. Vulcanisation is not the same, whether free sulphur or sulphur chloride, or even and more especially metallic sulphides, be the

vulcanising agents. 6. *Vulcanisation by free sulphur.*—Before formulating any theory relative to this process, it is right to recall some properties of normal rubber, which ought constantly to fix the attention of any one who wishes to study the phenomenon of vulcanisation. Hitherto the action of sulphur and its derivatives on normal rubber has more especially engaged attention, but neither the result of the action of heat at different degrees of intensity on normal rubber, nor the mode of action of different vulcanising agents *at these different temperatures*, in presence of rubber, has been taken into sufficient account. It is necessary to recall—(1) That normal rubber is to a certain extent porous. (2) That under the action of heat it expands. (3) That it may absorb by capillarity liquid and gaseous bodies in contact with it, and that more energetically as it is itself more expanded by heat. (4) That what we call rubber is not a fixed and determined hydrocarbide, but a mixture of at least two polymeric hydrocarbides of high equivalents derived from a fundamental hydrocarbide C_5H_8, and of which one possesses nervousness in the highest degree, and the other adhesiveness. (5) That, under the influence of heat, normal rubber commences to become viscous about 145° C. (293° F.) and to lose its elasticity, and it is only after prolonged cooling that this elasticity, the exclusive property of the nervous hydrocarbide, partially regains a part of its power: normal rubber, as soon as it has been once heated to the temperature of 145° C. (293° F.), will be partially and irrevocably innervated. This fact being taken as granted, the following is the way in which we interpret the complex phenomena which constitute vulcanisation by free sulphur (Goodyear's method):—The nervous hydrocarbide and the adhesive hydrocarbide are intimately mixed with the vulcanising body, sulphur—by the preliminary operation of kneading—at the moment when heat intervenes. Up to 118° to 120° C. (244·4° to 248° F.) no reaction takes place, but simple juxtaposition. From this point the sulphur modifies its condition, it melts at the same time that the pores of the rubber are sufficiently dilated to allow of the gradual absorption of the liquid vulcaniser, sulphur. But, at the same time as the chemical action commences, the liquid sulphur combines with the adhesive hydrocarbide, and forms with it a new chemical body, or rather an alloy. This action naturally continues if the process be prolonged at the same temperature, so that it penetrates further and further into the mass. Total penetration being attained, let us stop the operation (a good *cuiseur* knows perfectly when to seize the propitious moment for this purpose). Vulcanisation will have taken place, or rather the sulphuration of the adhesive body will have been accomplished. But the nervous substance will not have been attacked. But if the temperature be raised gradually so as to bring it to 145° C. (293° F.), the nervous hydrocarbide will lose its particular structure so as to be mixed up with the vulcanised part, and another reaction will intervene between the two bodies, namely, complete sulphuration resulting in hardened rubber or ebonite. *The phenomenon which we now include under the name of vulcanisation is therefore only the first stage of a series of transformations which the hydrocarbides constituting indiarubber undergo under the influence of fixed temperatures, and in presence of sulphur in excess, and the real terminal reaction of these transformations is hardened rubber or ebonite, which it is therefore necessary, so as to enter into the views of Carl Otto Weber, to regard as an amalgamation of one or more double atoms of polyprene (perhaps) by the intermediary of one or more atoms of sulphur. Vulcanisation is simply the result of a quick turn of the wrist on the part of manufacturers and experimenters to arrest, at the opportune moment, a chemical reaction which has but commenced, and the termination of which would, in no way, yield the product which it is desired to obtain.*

It will suffice to quote this characteristic fact in proof of the above contention: rubber in which an excess of sulphur has, by some means or another, been incorporated, and which remains supple after the *cuiseur* has judged his operation finished, may become hard and brittle some time afterwards. The reaction has not been arrested sufficiently either by the elimination of the excess of sulphur, or by a rapid enough dissipation of the intervening heat retained in the interior of the mass.

But rubber regarded as imperfectly vulcanised, as it comes from the vulcanising apparatus, may become sufficiently so, after some time, provided there be sufficient sulphur, and kept in a sufficiently warm place. Besides, the reaction arrested too soon may be re-started and brought to the desired point by heating. Payen's laboratory experiments support this contention. "Ether and carbon disulphide, kept for a long time in contact with vulcanised rubber, retain in solution 4 to 5 per cent. of rubber which may be isolated by repeated evaporations, and taking up each time by ether which eliminates free sulphur, then by anhydrous alcohol which removes 1 to 1·5 per cent. of fatty matter (?). The rubber extracted in this way may be separated into two portions—the one very ductile, dissolved by benzol, which deposits it on evaporation; the other more tenacious, less extensible, undissolved. These two portions come from the interior of the mass at a certain depth, where combination is less intimate and less abundant in sulphur than near the surface. Rubber, after vulcanisation, still consists of two portions, endowed with unequal cohesion and solubility, by keeping a vulcanised strip immersed for two months in a mixture of 10 of carbon disulphide and 1 of absolute alcohol. The dissolved portions consist of interstitial sulphur, which is removed after desiccation by a solution of caustic soda; there then remains the less aggregated, feebly resistant, yellow, translucent, organic substance (adhesive hydrocarbide transformed by sulphuration). The undissolved portion remains under the form of a tenacious strip, more brown and not so transparent (our nervous hydrocarbide not yet sufficiently got at by proximity to the transformed adhesive part)." The results of the experiment, with the exception of the fatty substance, were as follows:—

TABLE XXXVI.—SHOWING RESULT OF ACTION OF CARBON DISULPHIDE ON VULCANISED RUBBER (PAYEN).

Insoluble tenacious portion	65·0 per cent.
Soluble soft portion	25·0 ,,
Sulphur in excess	10·0 ,,
	100·0 ,,

Payen's fatty matter is nothing more or less than a little oxidised tacky rubber which always accompanies caoutchouc. The manufacture of medium hardened rubber, more supple than ebonite, less supple than vulcanised rubber proper, supports above theory sufficiently to allow of rapid absorption by the pores. We consider their action as the result of a true alloy, giving rise to the same effects as actual vulcanisation, with this difference that true chemical action does not occur; there is no transformation into ebonite at 145° C. (293° F.).

Vulcanisation by sulphur chloride.—As far as vulcanisation by sulphur chloride, bromide, and iodide, these substances are naturally liquid, and can thus more easily penetrate into the pores of the rubber, just softened in the carbon disulphide or other solvent in which the chloride is suspended. The liability to decomposition of the reagent in presence of organic matters with great affinity for haloid bodies generates free sulphur. The solvent partially replaces heat and facilitates the reaction, which besides limits itself to the first stage of the transformation. It does not become complete without the intervention of effective heat,[1] and then may go as far as the terminal reaction, the production of ebonite, provided that the quantity of vulcanising agent be sufficient.

Summary of C. O. Webber's conclusions.—The results of an investigation by C. O. Webber on vulcanisation may be summed up as follows: 1. The reaction of sulphur chloride on polyprene is analogous to that of sulphur chloride on the non-saturated hydrocarbides of the ethylenic series; it has the effect of joining two molecules of polyprene by the medium of one or several double atoms of sulphur,

[1] See Fawsitt's researches, *Moniteur Scientifique de Quesneville*, 1890, p. 1851 and May 1893.

giving rise in the molcule of polyprene to a number of ethylenic bonds corresponding with the number of molecules of sulphur chloride taking part in the reaction. 2. There exist at least ten chloro-sulphides of polyprene, formed by the combinations of two molecules of polyprene by means of one and even as many as ten double atoms of sulphur. 3. Vulcanisation by sulphur chloride depends upon the formation of these chloro-sulphides of polyprene. The state of vulcanisation is due to the double atoms of sulphur (single or multiple) which unite two molecules of polyprene. The chlorine, which is fixed at the same time in the substance, has no appreciable influence on this state of vulcanisation, although it has contributed in creating it, in the sense that it is the active chemical agent of the sulphur in the sulphur chloride. 4. The present method of vulcanisation by sulphur chloride is very irrational, because it cannot lead to homogeneous vulcanisation of the rubber. A sulphur chloride process, by which homogeneous vulcanisation would be produced, would be of incalculable practical value.

CHAPTER IX

CHEMICAL AND PHYSICAL PROPERTIES OF VULCANISED RUBBER

Here it is impracticable to work on a chemically pure substance. Vulcanisation is an unfinished reaction, arrested in presence of excess of vulcanising agent. It is thus difficult to determine the density and elementary composition of the product, its colour, its smell, or its taste. In this examination, the course pursued in the examination of the latex and (as pure as possible) rubber, is impracticable. The examination must be limited chiefly to a demonstration of its properties, by contrasting it with natural rubber, from which it differs essentially in many of its properties, both physical and chemical. Many of these properties are unimportant, either scientifically or technically.

Elementary composition.—It is quite impossible to give an elementary composition, however imperfect, or to ascribe any formula to vulcanised rubber. Those who have ascribed to it a definite chemical composition, have neglected to formulate it, and rightly so. A reaction, interrupted from one moment to another, according to circumstances, cannot be formulated.

Density.—Normal rubber has a density of 0·925; vulcanised, it rarely weighs less than water, and often goes as high as 1·20 and even 1·30. But it is evident that this maximum density is only produced by an excessive loading with inert matter, and that the elastic properties of the substance must thus be gravely compromised. A good vulcanised rubber ought always to have a lower density than unity, and this fact may be made to serve as a starting-point to establish a method of testing the purity of vulcanised rubber. A remarkable observation of Thomas (*Monde*, 1869), bearing upon this subject, has reference to the dilatability of rubber, which is great enough to render it necessary to take into account the temperature at which the density is determined. If a sample of rubber rather denser than cold water be taken, or a piece ballasted by means of a small piece of metal, if it be lighter than water, and the whole afterwards heated, the rubber, in spite of the expansion of the water, will very soon be seen to rise to the surface. According to Puschl and Schmilewitsch, *vulcanised rubber is a substance whose density becomes a minimum at a certain temperature. The temperature incidental to this minimum varies with the mechanical effort exerted on the rubber,*

Table XXXVII.—Showing Density of Different Sorts of Indiarubber (James Symen).

Rubber.	Density.
Para rubber crude as imported	0·922
,, ,, regenerated	0·882
,, ,, regenerated and pressed	0·935
,, ,, mixed with sulphur	0·990 } diminution
,, ,, unvulcanised	0·986 } 0·004.
Java rubber crude as imported	0·920
,, ,, regenerated	0·872

and is greater the greater the effort. Taking a rubber unstretched by mechanical effort, the temperature of minimum density is always higher than the ordinary temperature, and approaches it by an addition of caloric; its coefficient of expansion is positive, but diminishes in proportion with the increase of caloric. Taking, on the other hand, a rubber strongly stretched by a pulling force, the temperature of minimum density is lower than the ordinary temperature. Its coefficient of expansion is therefore negative, and will diminish numerically with the temperature.

It may be interesting at this point to draw attention to the experiments of Symen, to determine the density of rubber vulcanised by sulphur, compared with that of rubber to which other substances had been added.

TABLE XXXVIII.—SHOWING EFFECT OF VARIOUS MIXTURES ON DENSITY OF RUBBER (SYMEN).

No. 1. Pure.—Mixed with sulphur, but unvulcanised	1·024	decrease
,, ,, Vulcanised	1·013	of 0·011.
No. 2. Grey.—Mixed with sulphur, but unvulcanised	1·160	increase
,, ,, Vulcanised	1·180	of 0·020.
No. 2. Brown.—Mixed unvulcanised	1·145	increase
,, ,, Vulcanised	1·163	of 0·018.
No. 3. Grey.—Mixed unvulcanised	1·489	increase
,, ,, Vulcanised	1·520	of 0·031.
No. 3. Brown.—Mixed unvulcanised	1·451	increase
,, ,, Vulcanised	1·460	of 0·009.

The density of vulcanised Para rubber diminishes, its volume increases: other species, especially those which are strongly mineralised, have a greater density, whilst their volume diminishes. It is necessary to remember this when vulcanising in moulds.

Colour.—The colour of rubber may be appreciably modified during the vulcanisation. But that matters little, and need occasion no great concern. If one tint of vulcanised rubber be preferred to another, the methods of supplying it are well known.

Smell—Deodorisation.—The same remark does not apply to *smell.* Vulcanised rubber has a peculiar odour of its own, scarcely appreciable with an isolated small article, but which reveals itself very quickly if the temperature be raised from 35° to 40° C. (95° to 104° F.). Even at the ordinary temperature this smell is immediately felt on entering a room where there are articles of this nature. It is due to a slight disengagement of sulphuretted hydrogen, the presence of which is explained in the chapter, but also to the vulcanised rubber itself. The disengagement of sulphuretted hydrogen is greatly prevented by treating the vulcanised articles by alkaline solutions. So far as disinfection of the vulcanised substance itself is concerned, many methods have been proposed, but none succeed, because of the property which rubber possesses of absorbing and retaining gaseous, odoriferous bodies. Bourne's process for complete deodorisation of vulcanised rubber is based upon the great affinity which charcoal, more especially animal charcoal, possesses for all gaseous bodies. He covers the articles with finely pulverised charcoal, and allows them to remain so from three to six hours at a temperature of 40° to 50° C. (104° to 122° F.); after which they are taken out, having suffered no further change than that of having lost their smell and of being incapable of imparting any taste whatever to the liquids with which they are brought in contact. With certain precautions, even the most delicate fabrics may be so treated without altering their substance and their appearance. But the odoriferous principles are only partially absorbed, the charcoal only acting by contact, *i.e.* superficially, and after some time the odour reappears. Attempts have been made to mask the smell, and some scent employed as a palliative. Essential oils are, however, volatile, and the momentarily badly masked smell soon returns. It

would be a difficult matter to please the taste in scents of each individual customer.

Conductibility of heat and electricity.—It will readily be seen why vulcanised rubber is a still worse conductor of heat and electricity than normal rubber, and that this property only increases in proportion as the transformation becomes more complete. Sulphur, like indiarubber, is a bad conductor of heat and electricity; the two combined by juxtaposition, by alloy, or by chemical combination, therefore totalise the sum of these properties so as to render vulcanised rubber one of the bodies which most energetically resists the passage of these fluids.

Permeability—Power of dialysis.—The porosity of vulcanised rubber is less than that of natural rubber. The experiments of Payen, who discovered this peculiarity, have already been quoted. Samples of normal rubber, vulcanised rubber, and finally totally sulphuretted rubber, were suspended for two months immersed in water: the first had absorbed 0·2 to 0·26 of water, the second 0·042, and the third 0·064, *i.e.* natural rubber absorbed five times more water than vulcanised, and the latter a third less than that from which the free sulphur which obstructed the pores had been eliminated. Repeating these experiments on balloons of 2 millimetres ($\frac{2}{25}$ of an inch) in thickness, filled with water under a pressure strong enough to double their diameter, and keeping them at a temperature of + 16° C. (60·8° F.), Payen found a loss by sweating. This loss, per twenty-four hours per square metre of surface, was 23 grammes in the case of the normal rubber, against 4 grammes for the vulcanised. But, on repeating the same experiment with air instead of water, Payen only found but a barely appreciable loss after eight days' observations.

These results would lead to the conclusion that vulcanised rubber is less permeable to liquids without solvent action upon itself than normal rubber, but that the permeability to gas is the same in both cases. Such a conclusion is negatived by the curious observations of Julkowski on the dialytic power of vulcanised rubber for gases, and principally illuminating gases.

Julkowski's experiments on dialytic action of rubber on coal gas.—The experiments of this chemist show that vulcanised rubber removes from gas a portion of its illuminating power by the absorption of the heavy hydrocarbides. Relying on the data of Knapp, who in his *Chemical Technology* states that rubber rings used to connect gas pipes had notably increased in weight and appeared swollen, he showed that an illuminating gas of 11·2 to 13·2 candles was reduced to 7·5 and 10·7 candles by simple passage through a rubber tube 14 feet long. He also states that vulcanised indiarubber in contact with coal gas for fifty-one hours, absorbed 3·64 of its weight of hydrocarbide, which it gave up very rapidly under the air-pump, and more slowly in free air. Pure ethylene and benzol vapours are both given off from the hydrocarbides absorbed by rubber. Julkowski concludes that the use of rubber tubing always gives rise to a diminution, of little importance it is true, of the illuminating power of coal gas—a loss, however, which ought to be taken into account in photometrical tests.

Hempel's experiments on the absorption of CO_2 *and* NO *by rubber.*—Walter Hempel, with the view of determining the influence of indiarubber joints in gas analysis, submitted carbonic oxide and protoxide of nitrogen to the same tests. The rubber behaved exactly like a liquid solvent. He placed fragments of vulcanised rubber in a graduated flask, containing the above gases, until the graduations indicated absorption; he then replaced the unabsorbed gas by air. He thus demonstrated that very small fragments of indiarubber tubing of 3 centimetres (say $1\frac{1}{5}$ inch) in length, and from 4 to 5 millimetres (say $\frac{1}{6}$ to $\frac{1}{5}$ of an inch) in exterior diameter, had absorbed about 2 cubic millimetres of carbonic acid and 3 cubic millimetres of protoxide of nitrogen, and that these fragments afterwards placed in a measured volume of air completely gave up to it this same volume of gas. *Conclusions.*—If in very precise analysis indiarubber joints are debarred, moreover, the absorptive power of indiarubber is not so great that it need be considered in tests

where rigorous precision is not absolutely necessary; besides, the gases generally pass through glass tubes, and indiarubber is only used to connect these with one another.

Elasticity, compressibility, dilatability, extensibility.—These properties are highly important to industry in general, especially in motor-car, etc., tyre manufacture, and in the construction of railway rolling-stock transmission belts, etc. Vulcanisation has more especially modified and developed these properties to the great advantage of the raw material.

Stewart's experiments on the elasticity, etc., of vulcanised rubber.—A. Stewart, in charge of the Railway Management Course at the School of Mines of Liège, made experiments on vulcanised rubber, especially in regard to elasticity, and the manner in which it behaves when it is pulled and compressed.

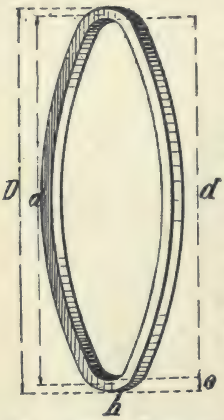


FIG. 86.—Indiarubber band used in Stewart's experiments.

All the experiments were made on one and the same species of specially vulcanised Para rubber. Its density was comprised between 1·060 and 1·065, and Stewart considered it as one of the best types of commercial rubber. Stewart preserved the majority of the pieces which were used in the experiments, and some of these would appear to have lost none of their elastic properties after eighteen years. But others had undergone those great alterations which often render vulcanised rubber absolutely unfit to be used for a long time for the purposes to which it is usually put. They have become hard, brittle, and almost like sealing-wax. Parallel with Stewart's experiments, Professor Emilio Villari, Bologna, undertook similar experiments. The results, although absolutely independent, agree and dovetail into each other upon several points.

Stewart's experiments on elongation.—These experiments were made on seven samples, having the form of bands or rings of rectangular section, very uniform, and of a rather large diameter compared with the transversal dimensions. The subjoined Table shows the different elements forming the data of the question, which were very carefully determined before testing.

TABLE XXXIX.—DIMENSIONS AND WEIGHT OF THE RUBBER BANDS SUBMITTED TO THE EXPERIMENTS (STEWART).[1]

	A.	B.	C.	D.	E.	F.	G.
D, Diameter, exterior	118·2	107·2	108·8	108·8	106·1	106·1	108·7
e, Width	9·2	5·2	5·8	6·0	4·8	5·0	5·5
d', Diameter, average	109·0	102·0	103·0	102·8	101·3	101·1	103·2
c, Circumference, average	342·0	320·9	324·0	323·0	318·0	318·0	324·0
Weight in grammes	36·95	18·75	11·4	11·17	9·48	8·59	18·81
Density	1·060	1·060	1·065	1·065	1·061	1·061	1·060
V, Volume	34·858	17·689	10·704	10·488	8·935	8·111	17·745
S, Section $=\frac{v}{e}$	101·92	55·28	33·04	32·57	26·53	25·51	50·77
h, Height $=\frac{s}{e}$	11·1	14·6	5·7	5·4	5·5	5·1	10·0
h', Height observed	10·9	10·4	5·5	5·4	5·3	5·0	10·2

The exterior diameter D is calculated according to the value of the exterior circumference measured directly; it is the only process which gave uniform results in several consecutive measurements. The width e, difference between the exterior and the interior radius, was measured directly by the thickness compass (callipers)

[1] All throughout the following the kilogramme and the millimetre are taken as unity, unless the unit be expressly stated.

giving the tenth of a millimetre. The average diameter d' is deduced from the two preceding values $d' = D - e$. The average circumference c is calculated by means of d'. The density was taken each time of the whole sample weighed consecutively in air and in water. The volume is calculated from the loss of weight in water. The meridional section S is obtained much more accurately than by direct measurement, by dividing the volume by the average circumference. Finally, for purposes of verification, there is placed side by side the height h, calculated by dividing the section by the thickness and the observed height h'. During the whole time taken up by the experiments, the temperature varied between 14° to 16° C. (57·2° to 60·8° F.). Table XL. gives the results of experiments made on the six rubber bands A, B, C, D, E, F. An important point will be observed at the first glance which is made at these figures, namely, that the

TABLE XL.—ELONGATION OF BANDS OF DIFFERENT SECTIONS UNDER VARYING WEIGHTS.

Load in Kilogrammes.	A.		B.		C.		D.		E.		F.		Remarks.
	Lengths.	Elongations.	Lengths.	Elongations.	Lengths.	Elongations.	Lengths.	Elongations.	Lengths.	Elongations.	Lengths.	Elongations.	
0	120	...	120	...	120	...	120	...	120	...	120	...	
0·5	...	...	125	5	130	10	130	10	133	13	134	14	
1·0	127	7	134	9	145	15	146	16	152	19	158	24	
1·5	130	3	143	9	165	20	164	18	181	29	193	35	
2·0	134	4	153	10	190	25	190	26	216	35	236	43	
2·5	139	5	167	14	221	31	219	29	258	42[3]	280	44[3]	
3·0	145	6	182	15	252	31[3]	251	32[3]	294	36	318	38	
3·5	150	5	200	18	283	31	281	30	328	34	351	33	
4·0	157	7	220	20	312	29	310	29	359	31	384	33	
4·5	164	7	241	21[3]	337	25	334	24	388	29	416	32	
5·0	171	7	262	21	361	24	358	24	414	26	440	24	
5·5	179	8	281	19	385	24	380	22	436	22	463[2]	23	
6·0	188	9	300	19	405	20	402	22	458	22	492	19	
6·5	197	9	317	17	425	20	422	20	478	20	510	18	
7·0	207	10	333	16	442	17	439	17	495	17	528	18	
7·5	217	10	348	15	459	17	454	15	514	19	546	18	
8·0	227	10	361	13	474	15	469	15	528[1]	14	560	14	
8·5	...	...	379	18	489	15	483	14	550	14	...	...	
9·0	248	21[3]	392	13	502	13	497	14	562	12	...	...	
9·5	...	...	406	14	515	13	510	13	575	13	...	...	
10·0	269	21	416	10	525	10	522	12	588	13	...	...	
10·5	...	...	430	14	535	10	535	13	600	12	...	...	
11·0	289	20	440	10	...	...	549	14	613	13	...	...	
11·5	...	...	454	14	...	...	558	9	620	7	...	...	
12·0	308	19	462	8	...	...	565	7	...	...	...	...	
12·5	...	...	472	10	...	...	576	11	...	...	...	...	
13·0	326	18	481	9	...	...	584	8	...	...	...	...	
13·5	...	...	...	...	...	...	..	...	...	...	...	...	
14·0	344	18	...	...	...	...	...	...	...	...	...	...	
14·5	...	...	...	...	...	...	...	...	...	...	...	...	
15·0	360	16	...	...	...	...	...	...	...	...	...	...	
15·5	...	...	...	...	...	...	653	69	...	...	...	...	
16·0	376	16	...	...	...	...	...	...	...	...	...	...	
17·0	390	14	...	...	...	...	...	...	...	...	...	...	
18·0	404	14	...	...	...	...	682	29	...	...	...	...	
19·0	418	14	...	...	...	...	...	...	...	...	...	...	
20·0	430	12	...	...	...	...	...	...	...	...	...	...	
21·0	440	10	...	...	...	...	...	...	...	...	...	...	
22·0	450	10	...	...	...	...	...	...	...	...	...	...	
23·0	460	10	...	...	...	...	...	...	...	...	...	...	

[1] The same weight continuing to act for some minutes, the length reached 536.
[2] Ditto, the length reached 473. It is on these figures that the elongation has been calculated.
[3] Maximum value of the elongation.

increases in length by successive additions of equal weights go on increasing up to a certain point, then gradually diminish to the end of the experiment. The extensibility of vulcanised rubber increases, therefore, with the load until it reaches a maximum, after which it diminishes in proportion as the load increases. The maximum elongation, per kilogramme, on the six bands tested was 240, *i.e.* double the initial length, measured between the bench-marks, from which Stewart formulates the following laws: *Under a uniformly increasing load the elongations of a vulcanised rubber band go on increasing up to the point where it has attained the double of its primitive length, after which the successive elongations have a decreasing value. The weight necessary to quadruple the length of the band is the triple of that under which it is doubled, whatever may be the section of the band. These elongations, which we can produce on rubber up to five or six times its primitive length without bringing tenacity into play, are not produced with metals, but to the*

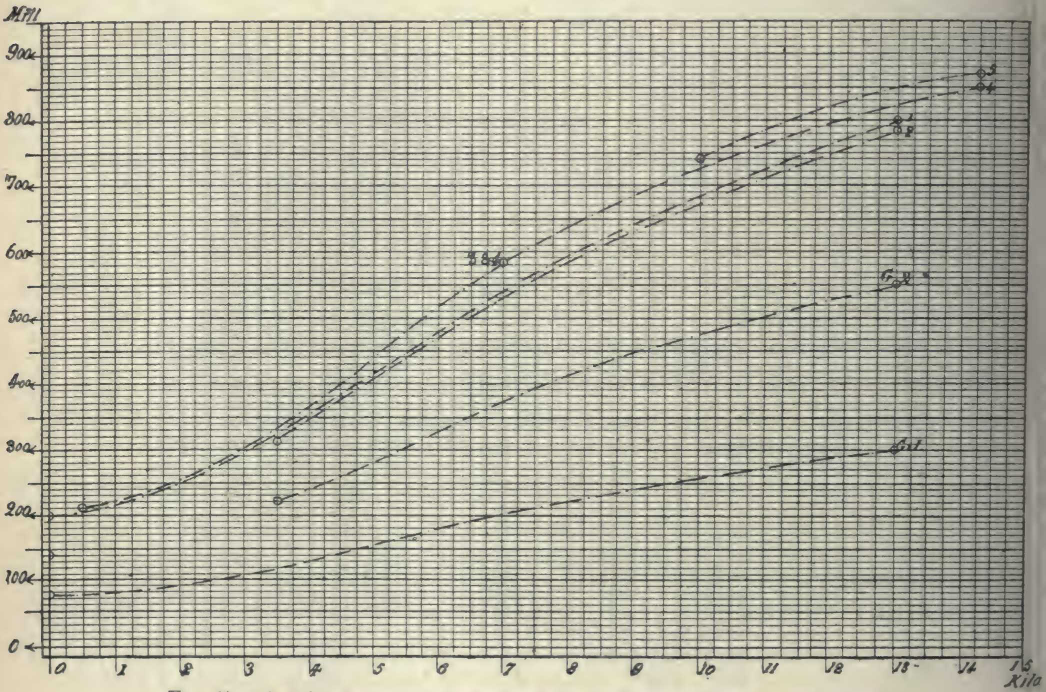


FIG. 87.—Graphical representation of elongation experiments on a rubber band.

extent of a few hundredth parts of their initial length. In this way an iron wire of 1 square millimetre of section would not double its length, except under 20,000 kilogrammes, and the extension is invisible except under a load of 30 or 40 kilogrammes, whilst a thread of vulcanised indiarubber of the same section doubles in length under a few grammes, and is not broken under a quadruple load. It remains to be ascertained whether the length submitted to the extension has any influence, and if so, to what extent the elongations vary, when the weights which produce them act during a greater or less length of time.

The band G (see Table, XXXIX.) was used to make five experiments upon this point. These yielded the results given in Table XLI., and traced graphically in the annexed diagram (Fig. 87). Experiments 1 and 2 were made simultaneously by measuring the distance between the two couples of arbitrary bench-marks on the band, giving the respective initial lengths of 75 and 140:

$$lo = 75 \text{ and } lo = 140.$$

TABLE XLI.—ELONGATION OF THE SAME BAND DURING SUCCESSIVE EXPERIMENTS (STEWART).

Load in Kilo-grammes. Band G.	Experiment No. 1.	Experiment No. 2.	Experiment No. 3.	Experiment No. 4.	Experiment No. 5.	Remarks.
0	75·0	140	200·0	200·0	200·0	
0·25	...	...	...	...	...	
0·50	77·8	...	211·0	211·0	...	
0·75	80·0	...	217·0	216·0	...	
1·00	82·3	...	223·0	223·0	...	
1·25	84·5	...	231·0	231·0	...	
1·50	87·5	...	239·5	239·0	...	
1·75	90·5	...	248·0	247·5	...	
2·00	93·8	...	257·0	256·5	...	
2·25	97·0	...	268·0	267·0	...	
2·50	101·5	...	280·0	279·0	...	
2·75	106·0	...	292·0	291·0	...	
3·00	110·5	...	305·0	304·0	...	
3·25	115·0	...	319·5	318·0	...	
3·50	120·5	222·5	335·0	335·0	...	
3·75	126·0	232·0	352·0	352·0	...	
4·00	131·5	243·0	370·0	369·0	...	
4·25	138·0	254·0	388·0	388·0	...	
4·50	144·0	265·0	406·0	407·0	...	
4·75	150·0 [1]	276·5 [2]	424·0	426·0	...	
5·00	156·0	288·0	443·0	445·0	...	
5·25	...	...	463·0	463·0	...	
5·50	169·0	310·0	483·0	481·0	...	
5·75	...	...	502·0	499·0	...	
6·00	182·0	332·0	520·0	518·0	...	
6·25	...	...	538·0	535·0	...	
6·50	193·0	353·0	554·0	552·0	...	
6·75	...	...	570·0	569·0	...	
7·00	203·0	373·0	586·0	584·0	...	
7·25	...	...	...	598·0	...	
7·50	213·0	393·0	...	612·0	...	
7·75	...	...	...	626·0	...	
8·00	224·0	414·0	...	639·0	..	
8·25	...	...	...	652·0	...	
8·50	...	...	...	665·0	...	
8·75	...	...	...	677·0	...	
9·00	241·0	444·0	...	689·0	...	
9·25	...	...	...	698·0	...	
9·50	...	...	...	709·0	...	
9·75	...	...	...	720·0	...	
10·00	258·0	475·0	...	729·0	743·0	
10·25	...	...	...	737·0	761·0	
10·50	...	...	...	744·0	770·0	
10·75	...	...	...	752·0	779·0	
11·00	272·0	500·0	...	760·0	788·0	
11·25	...	...	...	770·0	796·0	
11·50	...	...	...	781·0	806·0	
11·75	...	...	...	789·0	814·0	
12·00	286·0	525·0	...	795·0	820·0	
12·25	...	...	...	801·0	826·0	
12·50	...	...	...	808·0	832·0	
12·75	...	...	...	814·0	839·0	
13·00	300·0	550·0	..	819·0	843·0	
13·25	...	...	...	829·0	849·0	
13·50	...	...	...	835·0	854·0	
13·75	...	...	...	840·0	859·0	
14·00	...	...	...	847·0	865·0	
14·25	...	...	...	855·0	870·0	

[1] Maximum elongation per kilogramme, 24 millimetres.
[2] Maximum elongation per kilogramme, 44 millimetres.

The successive lengths under the same weight remain in constant ratio with those two numbers. In bringing the proportion of their initial lengths to 200, it is found in the same figure that the two curves almost coincide. The difference which exists between the two may be attributed to the fact that the readings of the distances were always made on No. 2 before No. 1. Owing to an accident, having broken the band, Stewart performed the experiments 3, 4, 5 with an unrolled band, the extremities of which were held between the jaws of two small vices lined with rubber, and it was thus possible to work upon a much greater initial length. The graphical curves were identical with those resulting from the experiment of Table XL., only their co-ordinates rise further in curve 3 than in curve 2, and in curve 5 than in curve 4. Stewart explains this phenomenon as follows: It has been noticed, for a long time, that if a rubber band be suddenly extended, a notable rise of temperature occurs which may be attributed to the diminution of its total volume. The experiments to elucidate this point are far from complete; certain authors assert an increase, others a non-alteration in volume. Thomson (Lord Kelvin) and Tait, in their book, *Elements of Natural Philosophy*, say distinctly: "An indiarubber band when pulled out experiences no sensible change of volume, though a very sensible change of length." Villari, of Bologna, on the contrary, obtained decreasing densities, in proportion as the extension of the rubber increased. The lateral deformation would therefore be in a contrary sense to that of all other bodies submitted to extension. This volume resumes its original dimensions at the end of a certain time. If the tension continue to be exerted, the length increases in consequence in such a manner that the elongation obtained suddenly is always less than that observed after a slow and gradual action. Stewart also made certain rupture experiments, which have added a final characteristic to the peculiarities of indiarubber, and which demonstrated to him that this substance *seems to have no limit to elasticity, except rupture.* At any rate, the two parts of the broken band, if they do not immediately revert to the primitive length, continue to shorten during a very long time more than twenty-four hours, and do not show after that any trace of alteration or of permanent elongation. The breaking load varied, according to the greater or less rapidity with which each experiment was pushed, from 500 to 800 grammes per square millimetre of original section; a band of 9·01 square millimetres of section was not broken under a load of 7·5 kilogrammes. The results of these experiments have, moreover, been adopted in actual practice, and the specifications of the Belgian State Railways embody them, so far as the supplying of the membranes required in its service are concerned (1888). The author sums up this first part of his work as follows:—1. *An indiarubber band, submitted to a longitudinal pull, immediately assumes a certain length, which notably increases if the load continues to act, but which when measured immediately is proportional to the primitive length.* 2. *That the relation between the length and the load which produces it is very complicated, and may be graphically represented by a curve, the degree of which is probably higher than the third, and which shows a point of curvature of which the co-ordinates are:* $x = ES$, $y = 2\ lo$; *lo* representing the initial length of the band, S the section, E the modules of rigidity or the weight necessary to double the initial length. 3. *That nevertheless the weight required to increase the original length in a given ratio is always proportional to the section.* 4. *That under a weight triple that which doubles the length the latter is quadrupled.* 5. *That the weight under which the length is doubled being* 80 *grammes per square millimetre of section, the value of the modulus of rigidity* E *is therefore* $E = 0{\cdot}084$. 6. *That if the definition of the modulus be rectified it will vary in the case of vulcanised rubber: in the beginning it has a value of* 0·168 *as a maximum corresponding to the minimum of extensibility; it afterwards diminishes to the third of this value at the moment when the length is doubled, then again increases to the point of rupture. It passes twice through the average value* 0·084. 7. *That the extensibility per unit of load added is variable: that it increases until the length is doubled, and thenceforward decreases.* 8. *That, finally,*

this maximum extensibility is exactly represented by the formula $e = \frac{3}{2}\frac{lo}{LS}$, *which gives the elongation for* 1 *kilogramme of load added at the moment the length is doubled.*

Stewart's experiments on depression.—When a solid body is enclosed between two parallel planes which a force tends to bring together, the body is said to be *compressed.* Ordinary bodies submitted to a rather considerable force of this kind suffer a slight diminution on the depth included between the two planes during compression, accompanied by a modification of the transversal dimensions, of which, generally, no account is taken so long as the limit of elasticity is not reached. This transversal deformation is estimated as being equal to the fourth of that which is observed in the direction of compression. It is altogether different with vulcanised rubber; that is why Stewart calls the action by which the rubber becomes deformed between the two approaching planes *depression*, whilst its dimensions, perpendicular to the force, increase to a considerable extent. Remark: *the sections normal to the compressing force enlarge whilst remaining similar to themselves.* Thus a round plate strongly compressed extends equally in every

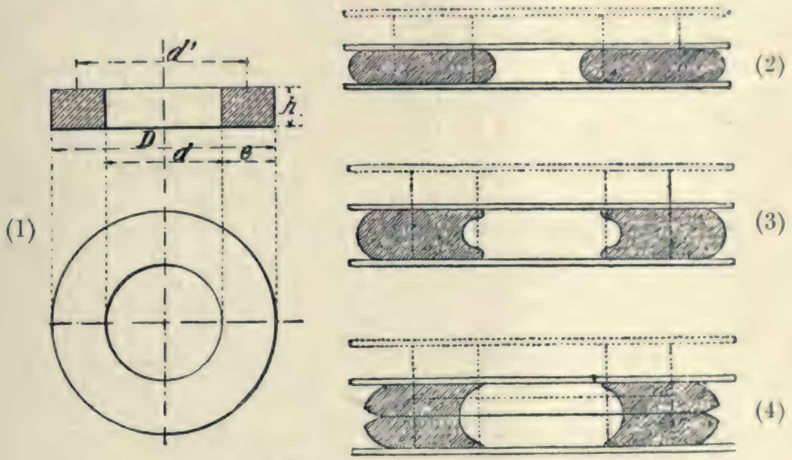


FIG. 88.—Effect of pressure on indiarubber bands.

direction, a square plate remains square, a rectangular plate is deformed according to a similar rectangle. The shape most often employed in industry is that of a ring of uniform rectangular section, Fig. 86; and this revolving solid is intended to resist forces directed along its axis. Such a body undergoes the following deformations: The parallel sections remain circles: Fig. 88 shows what happens to the meridional sections—the dotted lines show their original shape. They may be regarded as rectangles, terminated interiorly and exteriorly by semicircles, so that the surfaces not in contact with the parallel planes, and which were primitively two cylinders, become two semi-toruses (2). If the height h of the ring is much greater than its thickness e, the deformation takes place differently; the exterior toric surface remains convex, but the interior becomes concave, as shown in (3). This phenomenon commences when the height reaches $1\frac{1}{2}$ times the thickness.

$$h = \frac{3}{2}e.$$

If two superimposed bands be compressed, they at first behave as if the two were only one. Afterwards they separate, gaping at the point of exterior contact, as shown in (4). *But whatever may be the deformation undergone, vulcanised rubber invariably preserves its primitive volume.* The results of trials which experimentally established this fact are given in Table XLII. Pieces Nos. 1 to 7 were

bands having the form of Fig. 86; No. 8 was a full circular sheet, and No. 9 a square sheet, the whole of indiarubber identical with the preceding.

TABLE XLII.—INVARIABILITY OF VOLUME OF DEPRESSED CAOUTCHOUC (STEWART).[1]

		D, Exterior Diameter.	d, Interior Diameter.	h, Weight.	V, Volume.	Ratio of Extention to Volume.
1. Circular band . .	free	130	50	55	622,050	−0·0013
	loaded	193	36	22	621,214	
2. Circular band . .	free	97	45	26	150,080	+0·0088
	loaded	140	18	10	151,390	
3. Circular band . .	free	75	30	30	111,330	−0·0023
	loaded	120	16	10	111,090	
4. Circular band . .	free	120	68	25	191,950	+0·0100
	loaded	161	35	10	193,960	
5. Circular band . .	free	125	75	25	196,325	+0·0085
	loaded	165	42	10	197,970	
6. Circular band . .	free	119	85	17	92,599	−0·0059
	loaded	156	55	5·5	92,054	
7. Circular band . .	free	84	40	29	124,265	+0·0021
	loaded	129	28	10	124,530	
8. Circular sheet . .	free	110	0	22	209,066	+0·0003
	loaded	172	0	9	209,115	
9. Square sheet . .	free	110 side		24	290,400	−0·0048
	loaded	170 side		10	289,000	

The volume of each circular band was calculated by multiplying the meridional section by the average circumference. The differences between the volumes of free rubber and depressed rubber are very small, having regard to this primitive volume, and in no case exceed the error of a tenth part of a millimetre in direct measurement. The following law, experimentally true within the limits of actual practice, may therefore be formulated: *Throughout all the different shapes which a mass of vulcanised rubber may be made to assume, its volume remains constant. The flat surface varies inversely with the height*, or, when a circular band is concerned, *its average diameter extends in the same proportion as the meridional section diminishes.* Stewart thus thinks that if a cylindrical cavity was integrally filled with a mass of rubber of the same shape, the action of the piston in this cylinder would be as little perceptible as if it had been filled with water, *which is equivalent to saying indiarubber is incompressible to the same extent as fluids.* These experiments, made in 1871, were confirmed by W. Thomson (Lord Kelvin) and P. G. Tait in 1873. "Clear elastic jellies and indiarubber are probably all of very nearly the same compressibility as water." But Stewart differs slightly from Clapeyron: "The cubic compressibility of indiarubber measured in the workshops of the *Chemin de fer du Nord* was found equal to 0·00009295 of the primitive volume per kilogramme of pressure per sq. cm., which is about double the cubic compressibility of water" (*Comptes Rendus*, 1858, p. 112). Thus, during the deformation of a circular band of indiarubber, the substance *flows*, so to speak, a little towards the interior, much towards the exterior, producing considerable surface tension. It is the exterior surface which supports the maximum effort, and that at its equatorial circle. It is there, consequently. that rupture occurs when the pressure suffices. Stewart has seen pieces as neatly ruptured at the exterior equator as if they had been cut by a razor, resume their original shape when the pressure was removed, which confirms the idea that *even rupture does not lead to true permanent deformation.* A vulcanised indiarubber band undergoing elongation disengages a certain amount of caloric, and there is cooling absorption of heat when the matter resumes its original shape. They have, more-

[1] See note, p. 196.

over, observed that a band of vulcanised indiarubber, stretched by a weight which doubles its length, foreshortened one-tenth if the temperature was raised to + 50° C. (122° F.) (Joule and Thomson).

Adhesiveness.—This property, characteristic of natural rubber, is completely destroyed by vulcanisation. This modification of the properties of rubber under the influence of vulcanising agents and heat has already been sufficiently insisted on. It will suffice to state that vulcanisation causes indiarubber to lose its property of uniting with itself. Two sections of the same block, even very recently cut and brought together and pressed with considerable force, are no longer capable of uniting.

Action of heat.—Vulcanised rubber, unlike normal rubber, still preserves its pliancy and elasticity much below 0° C., and if it be subjected to tensile strain, however great, at a low temperature, so long as it does not reach the point of rupture, it reassumes its original shape when it is left to itself. It behaves similarly when heated, and it loses neither its elasticity nor its pliancy; at the heat of boiling water it is even more elastic, whilst at the same time it does not, like natural rubber, undergo viscous decomposition.[1] Brought to a temperature of 180° to 200° C. (356° to 392° F.), if the excess of sulphur be dissipated, it softens and melts, and when once melted it remains "tacky," and completely loses its elasticity. If the heat be maintained, the melted rubber becomes hard and brittle, until finally nothing remains but a charred mass.

Action of light.—The destructive action of light on normal rubber has already been described. Light acts similarly on vulcanised rubber, more especially if the rubber has not been freed from its excess of sulphur. Thomson found that even vulcanised rubber suffered to a greater extent than natural rubber, more especially as when light acts an elevation of temperature simultaneously intervenes. He considers desulphuration with alkaline lyes, not as a remedy, but as an aggravation of the evil; absorption of sulphur increases the volume of the rubber, and if, after vulcanisation, it be attempted to remove the excess of sulphur, a diminution in volume to 2½ per cent. results. A rubber so treated decays very rapidly, and Thomson explains it by the fact that the pores, originally filled with sulphur, then become filled with air. Hence arises oxidation, and (1) formation of hard brittle resins, and (2) of a soft greasy substance slightly volatile at the ordinary temperature. The action of light gave rise in 1866 to an extremely curious observation by Seely, who found that rubber mixed with free sulphur vulcanised equally as well under the action of light as that of heat. Industry has utilised the fact; and a thin leaf of rubber applied on a lithographic stone, and exposed to sunlight, can impart to that stone the property of retaining printing ink on the isolated spots. This is the point of departure of Caoutchoutocopy. There is no disengagement of light without a simultaneous disengagement of heat, and this singular phenomenon is thereby explained. Threads strongly stretched in vessels filled with different gases, and exposed to sunlight, behave quite according to the nature of the gas. In dry or moist oxygen, the threads break very rapidly, whilst in carbonic acid, hydrogen, and a vacuum they are completely unaltered (Thomson).

Action of solvents.—If vulcanised rubber be immersed for rather a long time in ordinary solvents—essential oils, benzol, carbon disulphide—it does not dissolve, but swells considerably, and, when the solvent has been completely eliminated, the properties of the rubber so treated are again modified. "Carbon disulphide, benzol, spirits of turpentine, and anhydrous ether swell vulcanised indiarubber to nine times its original volume; these vehicles may also dissolve and remove the excess of uncombined sulphur. Solution in anhydrous ether is very peculiar: at first a small portion is taken up and deposited on the sides, then, gradually, fresh quantities are dissolved, which go to enlarge the crystals adhering to the sides of the vessel, and even on the external sides of the sheets of rubber they may become bulky enough to show their octohedral form to the naked eye" (Payen).

[1] But the continuous passage of steam at ordinary or slight pressure through laboratory rubber tubing soon swells and bursts it.—Tr.

Benzine and carbon disulphide do not possess this property. If vulcanised rubber be left long enough in contact with spirits of turpentine at a high temperature, it is completely dissolved (Heinzerling). Ether and carbon disulphide dissolve 4 to 5 per cent. of vulcanised rubber, whilst they likewise dissolve the excess of sulphur. From the evaporation residue of this solution, $1\frac{1}{2}$ per cent. of soluble matter, oxidised caoutchouc may be extracted by absolute alcohol. Payen, by submitting vulcanised rubber to the solvent action of 10 per cent. of carbon disulphide and 4 per cent. of absolute alcohol, obtained the following results:[1] undissolved rubber, 75 per cent.; dissolved rubber, 25 per cent.

Action of oils.—The first observations upon the action of oils on vulcanised rubber are also due to Thomson. By treating threads successively with 1 to 100 per cent. of oil and setting them aside for six or seven years, he found that the threads, treated with a small quantity of oil, preserved all their properties and their elasticity, whilst a larger quantity facilitated oxidation. Rubber first forms, with the oil, a plastic mass, which finally oxidises very rapidly in the air. Cocoanut oil and palm oil acted most energetically, and castor oil had the least action. In the case of special decay in a fabric waterproofed by indiarubber, it was the excess of oil which was the determining cause of the mishap, and Thomson advises that, before waterproofing certain fabrics, a sample should be submitted for one or two days to a temperature of 100° C. (212° F.). More than 1 per cent. of oil in a fabric exerts a deleterious action on the rubber.

Action of atmospheric agents.—If vulcanised rubber were a well-defined substance, it would be interesting to study the alterations which it successively undergoes in air, light, heat, and humidity, either collectively or individually; this examination might perhaps furnish means of correcting the inherent defects of the transformed rubber. Vulcanised rubber is only the result of an incomplete and intermediate transformation between normal rubber and ebonite, the inherent defects in the substance can only be pointed out, attributed either to one cause or to another, and a few palliatives proposed; but to make a truly useful study, either for the elucidation of the scientific question, or for the purpose of perfecting industrial processes, such efforts would be useless and in vain. The turn of the wrist of the skilful workman, of the manager who is a good observer of daily facts, would be much more efficacious. Objects made of vulcanised rubber are liable to deteriorate in various ways. After a certain time, a molecular change occurs, which gives rise to a sort of fermentation, the pliancy and nervousness seem to disappear, and the rubber is sometimes quite deteriorated. This effect may be due to a slight humidity in the pores of the substance, and to insufficient heat during vulcanisation. Again decay manifests itself by a partial loss of elasticity in the rubber, which cracks over all the surface exposed to the air, the small cracks becoming accentuated towards the centre of articles, the rubber feels harsh, and ends by becoming pulverulent. If drawn out it breaks; it looks as if it had been burnt. Or the rubber softens, becomes pitchy, tacky; when drawn out it elongates but does not return to its original form. Sometimes it breaks. This defect, the result of insufficient vulcanisation, is still further aggravated by air and light, more especially by abnormal heat. This defect is similar to that in normal rubber, the final result of which is oxidised or resinified rubber. But the action is more energetic on rubber already enervated by repeated working in various ways during the long preparation of the substance, than with a virgin substance fresh from the hands of the producer. How to prevent or stop the decay which takes place sometimes on certain parts, whilst the neighbouring zones are sound is not known, It may be due to the unequal distribution in the mass of the vulcanised portions and the vulcanising substances. Even moonlight sometimes affects the quality of vulcanised rubber (Chapel). This, he says, has been observed numerous times on threads remaining under tension for several days. Chapel's observation may be classified amongst those real but inexplicable phenomena which those in the trade often come across, and are the cause of serious trouble. The action of the lunar

[1] ? Parts by volume or by weight instead of per cents.—Tr.

rays is often fatal to dyed drapery, and the sagacity of experts has not been able to afford a satisfactory explanation of mishaps of this kind. These mishaps may be mitigated by treating the vulcanised article with boiling baths of soda or potash, caustic or carbonated. But these washings only act superficially, and the evil soon reappears. Gerard's process of vulcanisation, called the alkaline process, also partially remedies these diseases of vulcanised rubber. But such remedies are merely palliatives; the evil, in itself, is insurmountable, because vulcanisation is not a finished operation. Vulcanisation by metallic sulphides would therefore be the best means to use, if it did not entail other drawbacks.

Action of reagents and metals.—Vulcanised rubber resists chemical reagents, acids, alkalies, and the greater number of salts, better than normal rubber. There is one exception, the action which metals exert upon it, or, more exactly, the action of vulcanised rubber upon metals,—iron, copper, and the alloys most commonly used for industrial purposes. These metals, in contact with vulcanised rubber, become corroded and, reciprocally, corrode the rubber. Either because the sulphur, in excess, has formed a metallic sulphide, or that the affinity of the sulphur for the copper and the iron is greater than for the hydrocarbide, the metals in contact with the vulcanised rubber become coated with a black layer of metallic sulphide, and the substance itself perishes and loses its natural properties. The same effect is observed with gold, silver, and lead; but that is a less important point: these metals do not often come in contact with rubber. If it be desired to avoid grave mistakes, these reciprocal corrosions must be taken into account. Hence, in the manufacture of electric cables, care must be taken not to apply vulcanised indiarubber directly on the copper wires. The wire would (1) rapidly lose its conductive power, and (2) the dielectric some of its efficacy. Again, in the making of moulds, where iron is the raw material preferably used, it is necessary both before and after each operation to clean the moulds perfectly with emery paper.

Reclamation and desulphuration of vulcanised rubber—Differentiation between (a) *normal rubber waste*, (b) *waste from unheated mixtures of sulphur and normal rubber, and* (c) *vulcanised rubber waste.*—If it be easy to utilise normal rubber waste, and also that of mixtures not yet vulcanised, since simple mixing suffices to restore almost entirely the whole of their properties, it is not so with rubber which has been heated with sulphur or its derivatives. If it is often indispensable in the manufacture of technical articles to free them after vulcanisation from an excess of sulphur, simply in juxtaposition, which would tend to exercise an ulterior prejudicial action on the quality and durability of the article, it is equally important to utilise factory waste, and articles condemned, either because they are defective, or because prolonged usage has made them unfit for further use. The almost absolute resistance of vulcanised rubber to the action of solvents does not allow this problem to be easily solved, and all the efforts of successive inventors have only ended in a palliative. Many methods have been proposed for utilisation of waste, and also for desulphuration of vulcanised rubber. Heinzerling classes them in three distinct categories—1. Mechanical division of waste, and use of the powder as an addition to virgin paste. 2. Fusion of waste, and use of the pitch as an addition to new mixtures. 3. Partial desulphuration and solution in appropriate solvents, evaporation of solvent, and utilisation of residue. (1) To the *first of these methods* belongs Goodyear's,[1] the oldest known process for reclamation of vulcanised rubber. He reduced the waste to a finely divided state, and then mixed it and combined it with normal rubber and the sulphur required by the latter, and used the mass so obtained for a fresh batch of vulcanised rubber, or the waste, impregnated with a little benzine, is digested from twenty-four to fifty-six hours in a closed, slightly heated reservoir; the waste swells to from three to four times its original bulk, and is thus easily reduced by the rolls to a very fine powder. This process appears simple and seems to solve the question. This is not so, however. The waste once vulcanised has undergone this first attack of the sulphur, and the heat which produced the incomplete transformation stopped at a desired point for the determined

[1] British Patent, 2933; 1853.—Tr.

industrial requirements of vulcanisation. Mixed with the sound part which has not yet been heated, the substance will certainly not behave, during vulcanisation, in the same way, and the product will not have the properties of good vulcanised rubber. Moreover, the vulcanising foreman would be quite at sea and would not know when to arrest the process. It is not so if the waste, swollen as above, be reduced to powder, and again passed through the slightly heated mixer. The sheets, of little consistency, it is true, may then perfectly well, either after compression in moulds, or in the state of powder, undergo the final treatment by which ebonite is produced. A rational use without any great expense is thus found for this waste. The only drawback is, that it occurs in rather large quantity, and the manufacture of ebonite is limited. (2) The *second* method of reclaiming waste consists in fusing the finely divided waste in a pot. A pitchy mass is obtained, extremely tacky, which, on cooling, becomes converted into almost solid blocks, if the surrounding temperature be sufficiently low. But if the operation be conducted during very hot weather, the product assumes a semifluid characteristic condition. This product, mixed with other substances—linseed oil, for example—may be used in waterproofing certain fabrics. Mixed with normal rubber, it may again serve to coat the canvas with which certain hose pipes with metallic spirals are surrounded. (See special chapter on Rubber Substitutes.) (3) It now remains to examine the *third* category of rubber waste reclamation processes. This method, moreover, is intimately connected with the question of desulphuration. The solution of this waste, in an appropriate solvent, would be the most rational reclamation process; it would naturally yield the most easily utilisable substance. But the true solvent has not yet been found, and all these processes run very dear.

Newton's process (British Patent, No. 1687; 1854), based on steeping from two to fourteen days in camphine (oil of turpentine rectified over bleaching powder), is not intelligible from the patent.

Heinzerling and Lipmann's British Patent, 1874.—The finely divided waste rubber is washed, then boiled in a 10 per cent. solution of caustic soda for some hours. After complete drying, the substance is run into a stove, heated by steam to a temperature of 80° to 100° C. (176° to 212° F.), in presence of benzol, spirits of turpentine, or other solvent of that nature, with which it remains in contact until complete solution is effected. To obtain a reclaimed rubber as free as possible from mineral admixture, the solution is allowed to stand to deposit, and the clear liquid is decanted, sometimes filtered; complete separation is thus effected. The solution is distilled in a retort by direct or indirect steam; the addition of appropriate substances prevents any initial vulcanisation. If an absolutely pure product be not required, the mass as it comes from the digester may be distilled. The evaporation of the solvent, which requires to be conducted at an extremely low temperature, must be as complete as possible, if it be desired to avoid blowholes and air-bells. In each batch only waste of the same composition if possible should be used. The waste is therefore sorted out into lots before being used. The more the shreds are cut up before being put into the digester the more rapidly will solution be effected. It is thus advisable to combine this process with the swelling and shredding previously described.

Burghard, Rowlay, and Salmonson's process (British Patents, 525 and 2340; 1878) (both provisional).—The object of these patents is more to free weighted rubber than to actually reclaim it. They treat the waste with hot hydrochloric acid, and so carbonise all vegetable fibre incorporated with the rubber, whilst any metallic oxides present, such as zinc, oxide, are also dissolved. The rubber is then dissolved in petroleum spirit, carbon disulphide, linseed oil, benzol, or any other solvent, by aid of heat, and the solution finally evaporated. If linseed oil be used as solvent, an ulterior treatment with ammonia is necessary. The residual caoutchouc is vulcanised afresh. The acid solutions contain the dissolved metallic salts, which can be precipitated as carbonate and again used. The novelty rests in stripping the waste and in the separation of the metallic oxides.

Nathaniel Chapman and Mitchell's process (British Patent, 5048; 1881,

which see for supplementary details).—In the same line of ideas Nathaniel Chapman and Mitchell patented in 1881 a special apparatus for the treatment of indiarubber waste by sulphuric or by hydrochloric acid, under a pressure of 50 lb. per square inch, Fig. 89. *A* is a vat with its lid *B*. Both are lead lined so as to resist the action of corrosive acids. Along the bottom of the vat passes a pipe *a*, pierced with holes, and from there branch out other cross tubes, likewise perforated; *a* ends in a vertical pipe *b*, which emerges from the lid. *b* communicates with the steam-supply pipe *d* by a movable indiarubber joint *e*. By lifting the joint the lid can be raised. *D* is a chimney for the disengagement of gases and vapours. It consists of two parts, *f* and *g*; *f* forms part of the body of the lid *B*, and is connected with the body of the fixed chimney *g* by a movable collar *h*. If the collar *h* be pushed on *g* the case becomes portable. A lead damper *i* serves to regulate the escape of steam and gas. The acid is poured on the bottom of the vat *A*; after which the waste is packed into it. The lid replaced, steam is run on from *d* into *b*, then into

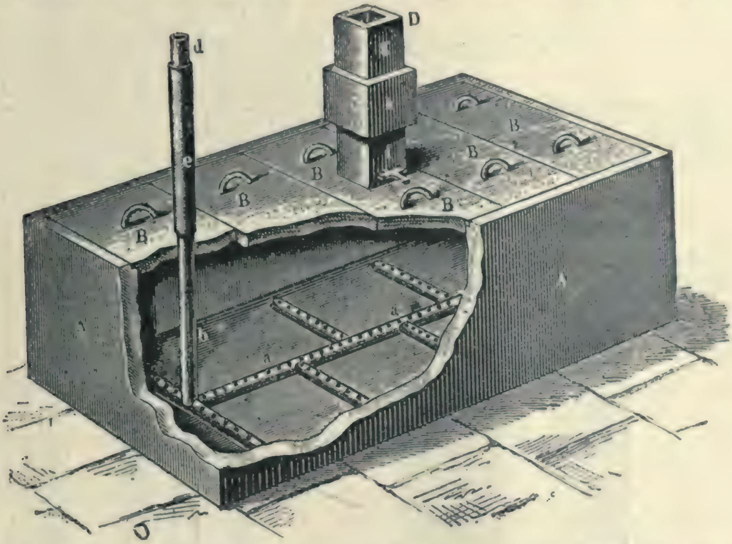


FIG. 89.—Chapman and Mitchell's apparatus for the regeneration of indiarubber waste.

a, and then spreads through the perforations throughout the whole of the acid liquid in the bottom. The pressure of steam ought always to equal 50 to 75 lb. per square inch. The process lasts from one to five hours, according to the composition of the waste. A syrupy mass is thus obtained, which, when drawn from the apparatus *A*, is passed through a washing machine to separate the rubber from the foreign bodies and the acid which accompany it. The rubber regenerated in this way is dried, then masticated, and wrought up afresh. The quantity and the strength of the acids necessarily depend on the quantity of foreign matter contained in the waste. The following are the proportions generally used:—

TABLE XLIII.—SHOWING AMOUNT OF MIXED ACIDS USED IN RECLAIMING RUBBER WASTE.

Waste	1000 lb.
Sulphuric acid 66° Bé., 168° Tw., sp. gr. 1·840	300 to 500 ,,
Hydrochloric acid	400 to 750 ,,

The vegetable fibres destroyed by the acids fall to dust at the slightest touch, whilst the metallic oxides are converted either into sulphates or chlorides.

Sulphuric acid is used on account of its energy and cheapness, but hydrochloric acid is preferable when more complete purification is desired. To swell the rubber by benzine, in this apparatus it suffices to close the chimney D by means of the

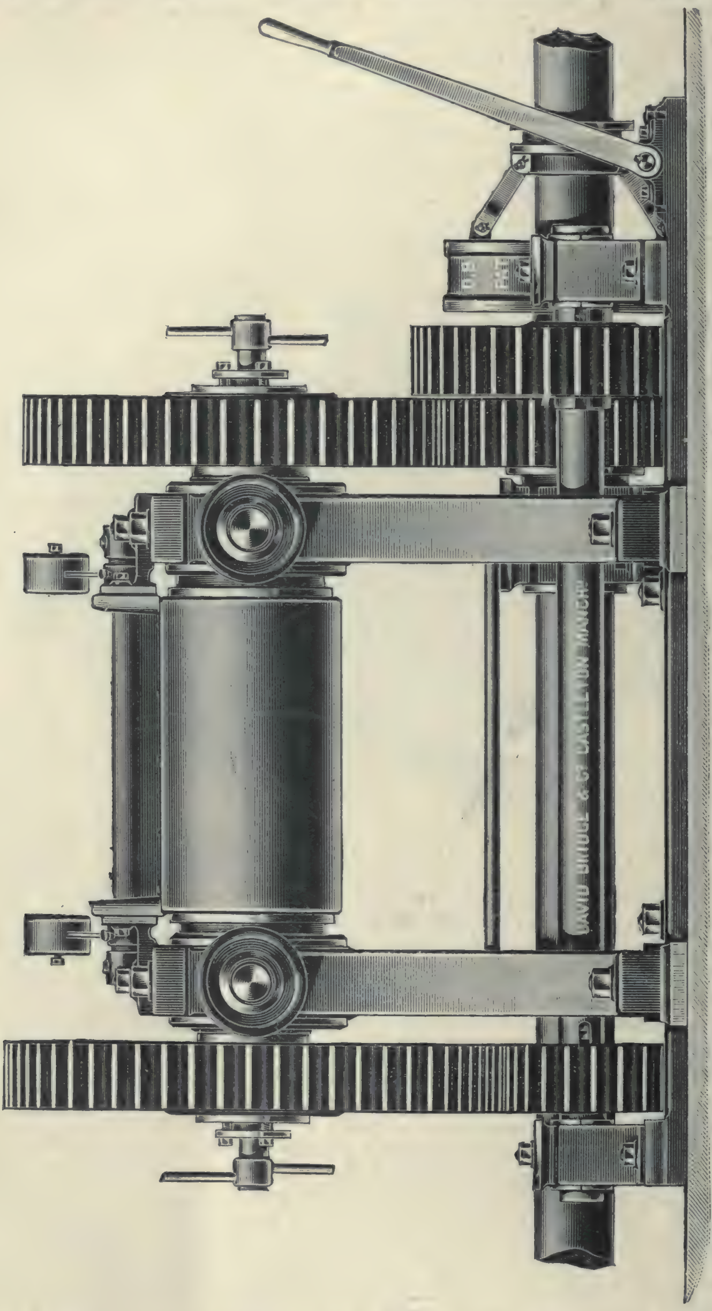


Fig. 90.—Fine grinding machine for fine grinding of old indiarubber tyres after passing through double-geared tearing-up machine.

damper i, until complete absorption, and then to open it afterwards. Waste from 3 to 15 per cent. of sulphur is only treated to eliminate extraneous matter, and the reclaimed mass then exists in the state of complete vulcanisation. If the waste is

not desulphuretted it can always be used up; in this case, moreover, it is always to be preferred to ground waste, the density of which is always much higher. A great drawback to the commercial articles made from reclaimed rubber is the disagreeable smell, from which it is impossible to free it, and which it communicates even to sound rubber. It has not been hitherto found possible to regenerate ebonite, which resists every known solvent, whatever may be the duration of the reaction. Such waste can only be utilised in the powdered condition, either by moulding and compressing by aid of some binding agent or by mixing the melted powder with fresh paste. Up to now we have only examined those desulphuretting processes which are used in the reclamation of waste. We have yet to speak of technical goods, where the problem is simply to eliminate by a simple process, but in as short a time as possible, the excess of sulphur which would injure the market value of the product. The excess of sulphur—the uncombined sulphur in juxtaposition—can very well be eliminated by the same processes as those used to remove the bad smell, *i.e.* by caustic or simply carbonated solutions of potash or soda, at a temperature of 80° to 90° C. (176° to 194° F.). But this is not done without injuring the goods to a certain extent. In this operation alkaline polysulphides are formed, with disengagement of carbonic acid. If the contact of the substance with the alkaline liquid in presence of heat is very prolonged, and if caustic alkaline solutions have been used in too great excess, the rubber becomes hard and brittle. Moreover, the desulphuretted matter, even under favourable conditions, again becomes so adhesive on its surface that articles so treated and piled above each other, after a certain lapse of time, become stuck together under the action of the pressure exerted: in this case the substance neither becomes hard nor brittle. In the case of real waste,—where it is necessary to extract, if not all the sulphur, at least a sufficient quantity, to re-endow the substance with the property of being attacked by the ordinary solvents, of being again wrought under some form or another, to restore to it the adhesive quality which it lost by vulcanisation, to render it apt to be vulcanised again in some manner or another,—the results hitherto attained have not always been in direct proportion to the efforts exerted.

Christopher and Gidley (British Patent, 1461; 1853) proposed "to macerate the vulcanised rubber in a hot solution of carbonated alkali, or in a solution of hydrate of lime, till, through the action of these reagents, the requisite quantity of sulphur is abstracted, that is, either as much sulphur withdrawn as reduces the relative proportion of the sulphur and the rubber to those required for any special purpose, or so far removes the sulphur as to leave the residual matter in a condition to be acted on by the usual solvents or softeners of indiarubber, so as to adapt it for re-formation into manufactured articles, and of being re-vulcanised with sulphur or other material when required. If the rubber be not in the form of bands, it must be reduced to small pieces so as to facilitate the action of the alkali or the lime, and the higher the temperature of the solution or of the water the more rapid is the operation. We generally employ the heat of boiling water, and, for economical reasons, we first boil with lime, which desulphurises on the surface, or to a small depth below the surface, then we run off the solution and the lime and then boil with a solution of carbonate of soda. At the end of a short time all the excess of sulphur or the uncombined sulphur is extracted, as well as the other substances introduced into the rubber during vulcanisation or after manufacture. In this state the desulphurised rubber is soluble in spirits of turpentine, naphtha, chloroform, and other liquids generally used to dissolve or soften rubber. . . .

". . . If it be found that the sulphur compounds thus formed, and which are partially dissipated into the atmosphere, are objectionable, a metallic oxide is added to the boiling solution: oxide of copper, for example, or a metallic carbonate capable of forming with the sulphur dissolved by the alkali an insoluble sulphide without disengagement of sulphuretted hydrogen."

Parke's process.—Before Christopher and Gidley, Parkes proposed to boil rubber waste in a solution of hypochlorite of lime until, by slight pressure, the pieces can

be readily united. He then washed the waste prepared in this way in hot alkaline water, and afterwards in clean hot water. British Patent, 11,147; 1846, gives the solution as one of muriate of lime.

These processes have a greater or less relative value which each manufacturer can alone appreciate. The same remarks apply to the palliative proposed for the first time by Newton (British Patent, 158; 1860), and which has since been remarkably improved.

Newton's patent.—But, little satisfied with the process of Parkes and Christopher and Gidley, Newton (communication from John Haven Cleever) patented a new process for treating waste vulcanised indiarubber (British Patent, 158; 1860). The waste rubber is first ground into a coarse powder and steeped in or mixed with wood tar or with crude turpentine (or with the tarry or pitchy products derived from the distillation of rosin when producing rosin oil), preferring what is known in the U.S.A. as pine oil, a semi-refined, dark sherry-coloured, rather limpid rosin oil.

The mixture of oil and ground rubber having remained from about four to five days, the superfluous tar or oil is run or strained off, and there is then to be added to the now softened rubber, by kneading, new or raw vulcanisable rubber, in any desired proportion to suit the quality as respects tenacity of the compound desired. Petroleum residues (British Patent, 2634; 1862) and vegetable oil pitches have been used, under pressure, at a temperature bordering upon ebullition. For certain special purposes these substances may be of use, but the matter dealt with is no longer rubber; it is a rubber *substitute.*

Summary.—If it be possible partially to desulphurise vulcanised rubber, this desulphurisation is never complete, and the portion chemically combined with 1½ *to* 2 *per cent. of sulphur always remains intact.* In a word, we do not yet know the chemical agent capable of producing the double decomposition of the substance called vulcanised rubber. Even if it were found, the desired end would not be attained, because after it had done its work the rubber obtained would certainly have lost the qualities which cause it to be esteemed.

The following is an abstract of a lecture by Mr. W. F. Reid to the Liverpool section of the Society of Chemical Industry. It shows what has been done in the way of reclaiming waste of late years:—

In the rubber industry all the output eventually becomes "waste," that is, it has become useless for the purpose for which it had been used. This "waste" finds its way back to the manufacturer for the recovery of the rubber. It was in 1846 when the first attempts were made to recover rubber from "waste," and in recent years a great advance has been made in this direction. The increased demand for rubber in late years for the electrical and motor-car industries has so taxed the supply that some process for the recovery of rubber from the "waste" has become more necessary. Last year the rubber output was 68,000 tons, there having been a large annual increase during the last five years. America is first with 42,800 tons, Brazil contributing 41,000 tons. Much has been said about Mexico rubber lately of an exaggerated nature. Africa produces about 23,400 tons, the Congo Free State contributing the largest amount. Ceylon rubber has not come quite up to expectations. Much of it is of good quality, but for some reason it does not find favour with the manufacturer. In the manufacture of rubber for industrial purposes the crude rubber is treated with sulphur for vulcanisation, and with filling materials as chalk, barium sulphate, litharge, etc. It is the sulphur which causes the difficulty in treating "waste" for the recovery of rubber. Vulcanisation at present is a necessity, but it is possible that some other substance may be discovered which will take the place of sulphur, and so make the recovery of rubber less difficult. Crude rubber will keep almost any number of years without deterioration; it is on account of the sulphur that rubber is perishable. The author here exhibited two pieces of crude rubber which had been kept for a number of years and were quite as pliable as when they first came into his possession. He had not been able to obtain any vulcanised which had been kept for nearly as long. He had a rubber stopper which he had had in his possession twenty years, but it was quite hard on the surface.

Of course it is the sulphur which makes the rubber so that it is not affected by changes of temperature, and renders it useful in the various industries, but he believed that inertness without sulphur may yet be possible. All old vulcanised rubber contains traces of sulphuric acid, evidently produced from the sulphur. At present rubber brittle with age cannot be renovated. The principal source of "waste" rubber is inner tubes and discarded tyres of motor-cars and cycles. This kind of "waste" material is the best available for the recovery of rubber, because, though physically useless for the purpose required, it has not chemically deteriorated, and is therefore well suited for the recovery of rubber. In regenerating or recovering rubber it is not necessary to remove all the filling materials. Fibre is the most troublesome to remove. *Mechanical methods are the best for removing fibre. The material is ground to a fine powder and the fibre blown out.* In some instances the fibre cannot be removed by mechanical means, and has therefore to be treated by some chemical process depending upon the nature of the fibre, the decomposed matter being washed out. There is some action on the rubber by the acid or alkali used which causes deterioration. Vulcanised rubber becomes insoluble in solvents which dissolve raw rubber, and only a portion of rubber can be dissolved out by the ordinary solvents for raw rubber. Many samples of recovered rubber on the market have been spoiled by overheating in the recovery process. Recently a French chemist has discovered a new solvent for rubber, and a factory has been erected for the recovery of rubber from "waste." The "waste" is reduced to a powder, and subjected to treatment with terpineol, a bye-product of the artificial camphor industry, and then diluted with benzine when the mineral matter settles down. The supernatant liquid is then treated with alcohol, which precipitates the rubber. This process produces very good rubber indeed, and is the best known to the author. There is a considerable amount of rubber recovered by old processes; in America alone last year 380 tons of rubber was recovered. In replying to the discussion which followed, Mr. Reid said that he understood the boiling-point of terpineol was high, and that it is very volatile in steam. The process takes place at from 100° to 150° C. He could not say what the cost of the production of rubber was by this process. He understood that there was plenty of terpineol available for this process of recovery. Rubber tubing keeps very well in water, light being the principal cause of deterioration.

CHAPTER X

HARDENED RUBBER OR EBONITE

Preliminary observations—Résumé of the theory of vulcanisation.—Vulcanisation properly so called is defined as only the first stage of a series of transformations which the hydrocarbides constituting natural rubber undergo under the influence of a high temperature in presence of an excess of sulphur. The real terminal reaction of these successive and graduated transformations results in the formation of hardened rubber or ebonite. The full and complete confirmation of this theory will follow from the attentive observation of the facts about to be described.

Goodyear's process.—The discovery of hardened rubber or ebonite is due to Goodyear.[1] In 1852 he communicated the result of his experiments. By using a larger proportion of sulpur, and by further increasing the temperature, indiarubber acquires the elasticity and durability of horn and whalebone, and, by adding other mineral substances, such as magnesia, zinc oxide, chalk, etc., it can be transformed into manufactured articles which could only be previously made from horn, ivory, metal, or leather.

Rapid development of the industry.—The manufacture of ebonite then made rapid progress, and from the new material articles of prime necessity, as well as *de luxe* articles, and even tools were produced.

Subsequent reaction.—But a reaction occurred about 1870: buyers rejected ebonite so much that it fell into discredit. The principal reasons are easily comprehended. In consequence of the grievous events on which it would be useless and inopportune to insist here, fashion neglected at this epoch objects of pure fancy or luxury, the ever-increasing applications of raw rubber raised the prices of ebonite articles so much that, although of superior value for the purpose, they could not compete with articles manufactured with less solid and resistant but cheaper materials, and the high price of the raw material induced manufacturers, at bay, to load their goods with inert substances in such a proportion that the quality of the goods, instead of being superior to similar articles, was often inferior in every respect. We have now returned to less fatal vagaries in this branch of the industry, and ebonite again begins to find favour with buyers. But it must not be forgotten that a substance—not absolutely indispensable in daily life—cannot hope to lead a long commercial career, except by its qualities, which should always be beyond all criticism. No longer must a technical writer be able to say, like Donath, in 1887, that "in ebonite articles the 'gum resin' only plays an accessory role in regard to the additional substances which form the base; it no longer intervenes as an elastic substance, but simply as an appropriate binding agent which is preferred to other cheaper agglutinants on account of its resistance to chemical agents and solvents" (*Moniteur Scientifique de Quesneville*, 1887, p. 77).

Secret processes and contradictory information.—"The essential processes of this manufacture are at the present time considered, with more or less reason, as veritable secrets. The data are so contradictory that one can flatly say that they are all more or less short of the truth. Goodyear, for instance, takes out a patent for curing at the temperature of 120° to 150° C. (248° to 302° F.), whilst other inventors affirm that a temperature of 160° to 165° C. (320° to 329° F.) is indis-

[1] British Patent, Nos. 6, 16, 19, 24, 28, 30, 33, 37, 43, 163; 1852.—Tr.

pensable. Some state that the process lasts four to five hours, whilst others assert that eight to twelve hours are required" (Heinzerling).

East Indian and Java rubbers preferred to Para and African rubbers in manufacture of ebonite.—All varieties are not equally esteemed for this special branch of the industry, and Para rubber is not that preferred by the trade, not because this substance does not possess the requisite qualities. In the beginning, Para was the only rubber used for ebonite, and very beautiful products resulted from its use; but as, in the special working of ebonite, elasticity (which is the property *par excellence* of Para) is destroyed by the fact of the vulcanisation being always pushed almost to the extreme point, it has not been found profitable to use nervous rubbers for this purpose. This way of looking at the matter has its justification so far, in the fact that it allows of the making of cheaper articles; and the majority of manufacturers at the present day prefer East Indian and Java rubbers to Para. African rubbers are less esteemed; they yield too dry, too brittle a product.

Improvement hoped for in African rubber.—It would be easy to explain this bad repute of African rubbers by the imperfections inherent to the present method of coagulation. But these methods are in the way of being improved from day to day, and before long we hope to witness a better appreciation of these raw materials.

Preparatory work—Ordinary vulcanising plant sufficient.—The work properly so called is divided, as in the case of other articles, into a preliminary preparation of the rubber, consisting in softening, washing, drying, masticating, mixing the rubber with sulphur and other conditions more or less useful, and the machines and tools for vulcanisation are more than sufficient.

Dose of sulphur increased according to nature of object.—The only difference (which naturally follows from the end in view) is that the proportion of sulphur is no longer the same. If it be desired to obtain goods endowed with a certain amount of pliancy and elasticity, like whalebone substitute, canes, etc., it should be less, say 12 to 14 per cent.; if, on the contrary, it be desired to obtain a paste suitable for making rigid objects, drawing-rulers, discs of electric machines, knife handles, buttons, etc., the proportion of sulphur should be greater, 24 to 35 per cent. The making of combs requires an intermediate quality, and the quantity of the sulphur should be so adjusted. The elasticity of hard rubber combs from different makers was found by Ebermayer to vary with the sulphur content. Those with a sulphur content of 11·95 per cent. could be easily bent but not fractured. Those with 21·46 per cent. were not easily fractured, whilst one with 28·25 per cent. was very hard and brittle indeed. In fact, combs are most often made from rubber with 20 to 24 per cent. of sulphur calculated on the weight of the rubber.

Minimum and maximum amount of sulphur.—Experience proves that the quantity of sulphur should never be less than 20 per cent., lest an incomplete reaction ensue and thus produce an ebonite destitute of all desired qualities. As an extreme limit, 35 per cent. of sulphur must never be exceeded, lest an absolutely brittle ebonite result.

Curing.—Whilst vulcanisation is the terminal point of the phases of supple rubber manufacture, it is not so with ebonite, except in a few instances. Two methods are available—the masticated and laminated paste is cured in sheets or bands of different thickness, then wrought as required by the turner with the file, the saw, the lathe, etc., just as whalebone, horn, wood, etc. The paste comes out of the mixer as a sheet, the thickness of which may be varied at will by bringing the two rolls nearer each other by means of the pressure screw with which they are provided, or, better still, by Mongin's mixer, the improved arrangements of which are such that a single touch regulates this distance in a perfectly uniform manner, which is not always the case with other mixers. For ordinary articles, the thickness is usually 2 to 7 millimetres ($\frac{2}{25}$ to $\frac{11}{40}$ of an inch). As soon as a sheet is rolled it is cut into tablets of the desired dimensions: for example, 60 centimetres in length by 40 centimetres in width (say 24 inches by 16 inches). These tablets

are still soft. They are collected on frames covered with moistened canvas, and immersed for a few instants in tepid water so as to render them firmer by freeing them from the excess of heat, and to enable them at that stage to contract to a certain extent. If this contraction were produced during curing, it would deform the articles. Finally, they are wiped, arranged on glass or on tin plates previously coated with a slight layer of an unctuous greasy body. A polished iron roller previously powdered with talc to prevent adherence is passed over them, and they are allowed to freeze, during twenty-four hours, in a horizontal position. They are then ready for curing by means of steam or superheated air. In curing by steam the frames on which the tablets are placed are arranged so that the latter are always inclined under an angle of 45°. This inclination is necessary so that the tablets do not sink or "run" when softened by the heat, and that the water which condenses during the operation cannot remain there. The steam is introduced so as to raise the interior temperature up to 135° C. (275° F.) very regularly and gradually, and from that point forward it is kept at that temperature during a fixed period of time. A few degrees above this temperature will burn the substance; a few degrees lower, and the want of regularity will result in the operation having to be done over again. The period when the temperature should have reached the desired degree varies with the thickness of the object. The same principle applies to the duration of the curing process, starting from the moment when the proper temperature is reached. With thicknesses of 9 millimetres (say $\frac{1}{3}$ inch) and under, the temperature ought to reach 135° C. (275° F.) in two or three hours, and the curing should not last longer than seven hours. With thicknesses of 10 to 12 millimetres (say $\frac{2}{5}$ to $\frac{1}{2}$ inch), the temperature ought to be raised more slowly to the desired degree in about four hours, and curing prolonged from that time forwards, during eight, nine, ten, and even twelve hours. This margin of two to twelve hours may appear rather elastic, but no fixed standard has been found for curing hardened rubber. Thus, pieces of the same thickness, consisting of the same ingredients, with the same proportion of sulphur, have been repeatedly cured at the same temperature and with identical supervision, and in eight hours the pieces have been perfectly cured; whilst on other occasions, after ten hours, the pieces had to be re-cured for from twenty minutes to three hours. Thick pieces are often quite cured, while other and thinner pieces are still underdone. When the curing process is judged to be complete the steam is turned off, the whole allowed to cool down for some time, then dismantling is effected, but the frames are not stripped until completely cold.

Differentiation between perfectly cured, undercured, and overdone goods.—When curing has been done to a nicety, the rubber is resistant and beautifully black. When it is not cured enough, it is soft, nerveless, like boiled leather, and of a greenish colour, which is deeper the nearer it approaches the perfect stage of the curing process. When curing has been pushed too far, so that the ebonite is burnt, it remains spongy, and resembles the blocks of soot agglomerated by pitch often found on the sides of chimneys; it is then irretrievably lost, and is not fit for any earthly use whatever.

Defects of the wet steam process.—The steam condensing in the vulcaniser causes drops of condensed water to fall back on the still soft sheets: now this condensed water brings in its train the lamellæ of rust from the inside of the cylinder, which sometimes digs holes in the sheets, and spots them right into the interior of the paste. Payen's remedy, consisting of a kind of protecting shield, seems only a palliative, and it would be better to obviate such an evil as is often done by substituting superheated air, or dry steam, for the action of wet steam.

Curing in the mould—Prevention of air-bells.—In certain cases the mixed paste is compressed into moulds in which it is immediately cured. But then air-bells are often disengaged between the paste and the side of the moulds, which cause damage. Engel proposes to remedy this evil thus:—The substance is compressed in the mould, previously filled with a liquid capable of mixing with the rubber, *e.g.* linseed oil. The compression exerted in all directions naturally pushes

out the liquid, and the inventor claims to eliminate in that way all traces of air-bells. The oil incorporated with the pasty matter, unless excessive, in no way injures the subsequent operations.

Danger of cracking in the mould.—If ebonite is to be made by moulding a soft paste of little consistency, there is danger of breaking or cracking during curing or subsequent cooling, owing to the difference between the coefficient of expansion of rubber and that of the moulds (brass, zinc, etc.).

Curing should not therefore be done in moulds unless in thin hollow articles, or objects which do not require to have a perfectly glazed surface. If the object, vulcanised in a mould, be too thick, the surface is covered with alternate elevations, sometimes remedied by protecting the paste before curing with a piece of tin, but there are still inequalities to be removed by the plane, file, etc., before the articles are marketable. In any case, moulded ebonite must be polished after cutting; it takes up time, and besides involves a considerable addition to the cost price. Moreover, moulded articles are difficult to polish.

Cowper's process (British Patent, 2288; 1858).—To obviate these drawbacks, Cowper exposed the objects to be vulcanised, in their brass or zinc moulds, from half an hour to three hours to the action of steam or a current of hot air. The temperature and the duration of this process vary with the proportions of sulphur and rubber. If as high as 1 of sulphur to 2 of rubber, Cowper recommends a first heating process of one hour at a temperature of 148° C. (say 380° F.). If the proportion of sulphur is less, the time must be increased proportionately. If the heat be greater than 148° C. (say 300° F.), less than an hour will be required. The mould is then allowed to cool, and removed from the articles, which as yet are only partially hardened. All defects, such as blisters, holes, or asperities or other surface imperfections, are now apparent; and the manipulator first covers them with a slight layer of rubber solution, and the holes are then filled up and smoothed with the original paste to be vulcanised, and the mended articles are then pressed again in the mould and the heating resumed for a half to three hours at such a fixed temperature as the case demands.

If the heating be done in a bath of wet steam, care must be taken not to let water penetrate into the moulds, which are therefore hermetically sealed.

This second heating does not yet produce perfect ebonite; the articles are removed from the mould to pass a fresh inspection. If still imperfect, the mending and heating is repeated as before. If otherwise, the article is placed loosely in a box without the mould; this box with the loose articles is then hermetically sealed, and the hardening is completed by a final heating, which may vary from six to eight hours. A practised hand can thus make articles of a restricted size with a single re-heating, whilst those of larger dimensions, whatever be the skill of the workman, nearly always require two re-touchings and consequently two re-heatings. Nevertheless, the articles as they come from the boiler have always a dull appearance, and show seams which have to be pared or filed, and if there be punctures, they must be filled up with shellac. They are then polished with emery or pumice-stone and oil, and finally they are polished if need be with rounds of felt.

For articles requiring a more perfectly polished surface, Cowper uses two different moulds. In the first, the first preparatory heating is conducted, and the object as it comes out of this first mould undergoes the necessary mendings and re-touchings. When the mass so treated has acquired about three-quarters of the desired hardness, it is then removed from the heat and from the mould, and is deposited in the second mould, in the interior of which are engraved the finer and more delicate designs. The article is then firmly pressed into the mould, and the hardening is completed.

Otto and Traun's process.—They harden rubber in glass moulds, the interior surface of which is dressed *en mat* (ground flat and smooth). The single or made-up articles made by this process have, it is claimed, a perfectly homogeneous texture and do not require any re-touching. The sheets of ebonite obtained on

frosted glass have the brilliancy and uniformity of cut glass, and come out of the vulcanising apparatus with an intense black lustre not otherwise attainable up to now.[1]

Powdered ebonite.—Ebonite powdered by the rasp is used as a solder to join the different faces of boxes and coffers. It is employed in that condition daily to produce by moulding and pressure a host of objects of complicated or delicate shape, such as statuettes, knitting-needles, umbrella and parasol handles, knife handles, imitation deerhorn, picture-frame ornaments. When agglomerated by heat and pressure, the grains of this powder form a coherent surface which perfectly espouses all the *delicate* intricacies of the moulds, and which can be brightened with metallic and other incrustations absolutely like shell.

Colouring ebonite.—"The Americans," says Chapel, "are able, it would appear, to colour ebonite superficially by two processes, of which we shall term the one dusting or sprinkling, and the other veneering. *Dusting* consists in sprinkling the sides of the mould with finely powdered colour, and moulding and vulcanising the article therein. *Veneering or enamelling*—Here the object itself is covered with a sheet of coloured rubber, after moulding it in the press, so as to cause it to take the imprints of the mould in which it is replaced to be vulcanised. We tried to enamel hardened indiarubber by Brianchon's process—a process which had a great success in the ceramic arts thirty years ago. This inventor was able to impart the multicoloured lustres and reflections of pearl to porcelain by means of a composition of which nitrate of bismuth, rosin, and Venice turpentine formed the base. We covered the small cubes of hardened rubber with this varnish, and introduced the sample into a decorator's[2] furnace and left it there for ten minutes at a temperature of 300° C. (572° F.), and we obtained a most beautifully brilliant effect. During the operation the heat in no way altered the cubes, the edges of which preserved all their distinctness. This enamelling process might receive useful applications, and would enable coloured articles to be produced if metallic oxides, like those used to colour porcelain, were incorporated with the varnish."

Enamelling with a coat or veneer of ebonite.—Ebonite, in virtue of its elasticity and durability, has been applied as a protective enamel or veneer to metallic objects. The article is coated by means of a brush with a solution of indiarubber dissolved in petroleum spirit or benzol, after which it is dusted over with flowers of sulphur. When the first coat is dried the same treatment is again applied, and when the second coat is dried the articles so treated are vulcanised by rapidly heating them to 160° to 170° C. (320° to 338° F.). The articles when taken out of the vulcanising apparatus are enamelled with a coat of ebonite. Bad spots can be made good by giving the article another coat, and again dusting it over with flowers of sulphur and once more vulcanising. To produce a superfine jet black, the object should be dusted with either gas black or Frankfort black, after being dusted with flowers of sulphur. Lampblack should not be used; it is too greasy, and cannot be so readily brushed off as either of the above-named blacks.

Colouring.—More massive enamels may be made by applying to the object to be so enamelled a rather viscous solution of indiarubber, previously mixed with the colouring principle and sulphur calculated on about 12 per cent. of the weight of the original rubber, so as to obtain a mixture having the consistency of thick liquid paint. If too viscous to apply with a brush, it may be thinned with turps; or if too thin, pigment may be added to bring it to the right consistency. If benzene or carbon disulphide have been used as vehicle or thinners, great difficulty will be experienced in evenly applying the viscous coating. The best results are obtained by swelling the rubber in benzene or carbon disulphide, and thinning down with turps or rectified petroleum spirit. The successive coatings should be thin, the necessary thickness being obtained by applying several repeated coats. Marbled designs can be produced on a white ground by tinting with different colours. When the desired result is attained, the coat is first of all dried at a temperature not exceeding 100° C. (212° F.), and any bad places made good. Finally, the

[1] See also British Patent, 4944; 1878.—Tr.

[2] ? Japanner's oven or stove.—Tr.

whole is vulcanised at a temperature of 160° C. Ebonite enamel so made is susceptible of a magnificent polish, and its adherence to metal is very great. Moreover, it is capable of withstanding a temperature of 200° C. (392° F.). It can be used for enamelling the outsides of stoves and such like.

Semi-hardened rubber is produced by diminishing the proportion of sulphur in the mixture, whilst at the same time the heat is not pushed so far. It responds to a limited demand when absolute rigidity in the article is not required. Articles are so prepared which, having a rather compact grain and great resistance, yet still possess a relative elasticity. Certain articles ought to be made so as to be very pliant in certain points, whilst other parts should be very hard and resistant. The result is obtained by alternating pliant portions with hard portions. So as to prevent the pliant parts from hardening during heating, mixtures of only 3 to 4 per cent. of sulphur are used; they stand heating for a long time without alteration.

Properties and multitudinous uses of hardened rubber (ebonite).—Ebonite in several of its properties resembles wood, horn, ivory. Its polish is superior, and it is much preferred in the making of small and large imitation horn combs, because it supports the cleansing action of hot water better than horn. Hot water does not cause ebonite to become rough to the touch and to be liable to crack like horn. Even after prolonged usage, the teeth of such toilet articles remain sufficiently smooth, and good quality ebonite is sufficiently elastic not to break under a rather perceptible bending strain. It is a substance eminently adapted for the development of static electricity, by rubbing, which justifies its use in the making of the discs of electric machines. Its dialectric properties are well known, and explain its use as an insulator for electrical cables and apparatus in which electricity plays the preponderant rôle.

Action of acids, etc.—It resists the action of strong acids, such as sulphuric and hydrochloric acids admirably, and thus justifies the application which has been made of it in the construction of pumps, taps, and hose specially intended for handling corrosive liquids. Owing to its rigidity at the ordinary temperature, rules, set squares, netting-needles, buttons, etc., may be made from it. Its colour, an intense black, aided by the natural polish with which it is endowed, enables it to be made into relatively cheap articles of ornament and luxury. *Solvents.*—It is insoluble in ordinary solvents for raw rubber and vulcanised rubber. Carbon disulphide and coal-tar hydrocarbides are only capable of making it swell slightly. *Coefficient of expansion.*—It posseses, in the highest degree, the property of expansion. Kohlrausch, in determining its coefficient of expansion, found that it was three times that of zinc.

TABLE XLIV.—SHOWING EXPANSION OF EBONITE AT DIFFERENT TEMPERATURES.

For 1° C. ebonite expands—

0·0000770	between 16°·7 and 25°·3 C. (61°·86 and 77°·54 F.).
0·0000842	,, 25°·3 and 35°·4 C. (77°·54 and 95°·72 F.).

This coefficient thus increases with the temperature. Two bands, one of white iron, the other of ebonite, soldered together, warp appreciably when slightly heated. It is the same with ivory. A small sheet of ivory (8 in.), united by isinglass to a sheet of ebonite, becomes an excellent thermometer without any need of a thermometric scale; the terminal unglued part elongates several millimetres for each degree C. of rise of temperature. A simple plate of ebonite shows, moreover, the singular property of this substance of becoming dull and warping when the mass is unequally heated. If only one side of a plate be heated, it immediately becomes perceptibly dull. The above coefficients of expansion show, moreover, that ebonite possesses a power of expansion equal to that of mercury, if + 0° C. be taken as the point of departure; if the point of departure be higher, this power is even greater.

Summary. — These are the salient features of ebonite, a product of the action of sulphur in sufficient quantity, and under the influence of a certain temperature, on normal rubber. The physical and chemical properties of ebonite

have nothing in common with the natural and primitive product. Rubber, as imported, is excessively liable to decay under the influence of atmospheric agents; vulcanised rubber is less so; and ebonite not at all. If heat still appears to have some action upon it, the effects thereof are diametrically opposite if the initial condition and final result be considered. Natural rubber yields at high temperatures volatile products and liquids of different densities and compositions; ebonite only gives a final product, carbon. Finally, if natural rubber has for the greater part of the time a faint odour of its own, if pliant or vulcanised indiarubber be easily known by its quite peculiar odour, from which it is difficult to free it definitely and completely, hardened rubber is completely inodorous, although the proportion of sulphur be infinitely greater. There, again, is one of the most powerful arguments that could be invoked in favour of our theory of vulcanisation. The same remark applies to the property of ebonite of producing, with time, neither efflorescence of any sort—the special property of vulcanised rubber; nor resinous pitchy matter—the special property of natural rubber.

CHAPTER XI

CONSIDERATIONS ON MINERALISATION AND OTHER MIXTURES —COLORATION AND DYEING — ANALYSIS OF NATURAL OR NORMAL RUBBER AND VULCANISED RUBBER.

Preliminary Observations.—The impurities and the inert substances which indiarubber may contain, either accidentally or fraudulently, have been dwelt upon sufficiently in Chapter III. But normal rubber that is sufficiently purified by special treatment, so as to be capable of being used in the manufacture of technical articles or to undergo the different phases of the transformations which terminate in vulcanised rubber and ebonite, would not always, by itself alone, be adapted for the numerous purposes for which it is intended. There are even cases where no single natural rubber of unique origin will answer the desired requirements, and recourse must be had to mixtures of rubbers from different sources. Thus, in the preparation of very elastic articles of a white colour, Para is often mixed with Madagascar and fine Borneo. To reduce the price, inferior quality rubber is mixed with superior quality. The waste from natural rubber is often used in that case, and without drawback.

The endless series of substances incorporated with rubber.—The manufacturer, according to the different uses to which he intends to employ it, must therefore impart to it new properties which it does not naturally possess. The incorporation of sulphur and its derivatives, as already seen, modify to a greater or less extent the nature of the normal article. To impart to the substance a greater or less degree of consistency, to colour it with different hues, to give it more or less weight, and thus allow cheaper articles to be made, an endless series of substances are incorporated with it. Some are useless, from a technical point of view; others only serve to load the manufactured article, most generally to the detriment of its quality and durability. A rubber for ink erasers is not necessarily heavily loaded with barytes, silica, ground pumice, etc.; it is the rubber that should wear, not the paper, and the rubber should not act on it like a file. The numerous compositions so made, says Chapel, are the subject of receipts which each manufacturer preserves with great secrecy.

Difficulties in matching samples.—It is not enough to know the substances which enter into the composition of any given mixture; to produce a similar article, there are proportions to be observed. Even with numerous gropings in the dark, it is, if not impossible, at least very difficult to imitate a product, so long as the exact quantities of the substances entering into its composition and the details relating to its vulcanisation have not been determined. We now proceed to enumerate the chief substances employed in the industry for either one purpose or another. To increase hardness and elasticity, gutta percha, corrongit,[1] balata, and rosin are chiefly used, but the latter body only in limited quantity; whilst numerous other substances, such as chalk, plaster of Paris, calcined magnesia, asphaltum, coal-tar, only serve to increase the bulk, to the detriment of the quality. Magnesia, however, has the property, more than any other addition, of hardening the rubber. There can thus be incorporated with the rubber as much as 80 per cent. of foreign substances, in the form of impalpable powder, without rendering it unfit for certain intended uses. It is in vulcanised rubber that these additions are now chiefly used, and the mixing is always done during mastication, at the same time as the sulphur or metallic sulphides are added.

[1] A species of elastic bitumen, particulars of which are given under "Rubber Substitutes."

Table XLV.—List of Organic and Inorganic Substances that are or have been mixed with Manufactured Indiarubber.

Albumen.	Chrome green.	Epsom salts.	Gypsum.	Paraffin.	Starch.
Asbestos.	Clay.	Fibrin.	Iron, oxide of.	Pitch.	Stearine.
Asphaltum.	Coke.	Flock.	Lamp-black.	Plaster of Paris.	Talc.
Balata.	Collodion.	Fucus.	Leather waste.	Rape oil.	Tar.
Barytes.	Copper oxide.	Gelatine.	Lime, caustic.	Red lead.	Tungstic salts.
Bitumen.	Cork.	Glue.	Lime, slaked.	Sawdust.	Varnish.
Camphor.	Cotton wool.	Graphite.	Litharge.	Shellac.	Zinc oxide.
Casein.	Dextrine.	Gum-arabic.	Magnesite.	Soap.	Zinc salts.
Chalk.	Earths.	Gutta percha.	Muræ.		etc. etc.
Charcoal.	Emery.				

Table XLVI.—Indiarubber Compositions for various Purposes.

	A.	B.	C.	D.	E.	F.	G.
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
Rubber	100	100	280	280	280	280	280
Garnet shellac	20	...	...	...	...	...	...
Calcined magnesia	20	40–50	...	...	...	...	...
Sulphur	25	20–25	...	...	...	...	84
Antimony pentasulphide	25	40–50	...	...	...	...	...
Coal-tar pitch	...	50–60	...	...	...	...	...
Powdered emery	...	...	1120	...	...	...	1120
Graphite	...	...	...	512	488	...	...
Lamp-black	...	...	$6\frac{1}{3}$	$6\frac{1}{3}$	$6\frac{1}{3}$	...	...
Zinc, white	...	...	...	...	...	84	...
Yellow ochre	...	...	...	...	...	1120	...

A., artificial whalebone; B., plastite; C.–G., composition for grinding, sharpening, and polishing knives.

Many of these substances find a useful application in special cases, others are chiefly used in the making of *rubber substitutes*, intended to take the place of indiarubber in the manufacture of cheap goods.

Colouring and dyeing.—Maigne has made a special point of summing up the facts known up to now. We quote him as follows: "Artificial tints are often given to rubber, so as to vary the appearance or to produce more or less artistic effects. This result is obtained in two ways: either by mixing the rubber in paste or in solution with mineral matter in impalpable powder, or by treating it after the manner of dyeing." The powders the most frequently employed are the following:—

Table XLVII.—Pigments used in Colouring Rubber.

Colours Required.	Pigments Used.
Red	Vermilion, red lead, antimony sulphide.
Orange red	Mars orange.
Blue	Ultramarine blue, Prussian blue, cobalt blue, indigo.
White	Zinc oxide, zinc sulphide.
Green	Guignet's green, chrome green, Scheele's green, emerald green, verdigris, terra verte.
Yellow	Cadmium, sulphide orpiment, yellow ochre, chrome yellow, oxide of uranium, chromate of zinc.
Black	Ivory black (*i.e.* bone-black), lamp-black (lead oxides and salts[1] give black lead sulphides with vulcanisation sulphur), seldom used.

[1] Black lead sulphide is often used as a vulcanising agent. It gives excellent results and increases the elasticity.

Dyeing methods have hitherto hardly been applied satisfactorily, except by means of alkanet root or aniline dyes. The incorporation of coloured linoleates —made by dissolving an aniline dye in a linseed-oil soft soap and precipitating by a suitable reagent — might prove an excellent method of colouring rubber. Unfortunately self-coloured metallic linoleates would not withstand the action of the vulcanisation sulphur. It is necessary, in fact, to work upon substances which dissolve rubber, and these substances are not common. Lightfoot has suggested to dye the rubber by previously covering it with a layer of gelatine, to act as a mordant. In one of his patents, Parkes speaks thus of the dyeing of indiarubber :—

"In order to dye it black, it is heated for a quarter to half an hour in the following preparation :—Sulphate of copper, 50 lb.; water, 40 to 50 gallons; ammonia or ammonium chloride, 50 lb: or boil the rubber in—bisulphate of potash, 50 lb.; sulphate of copper, 25 lb.; water, 40 to 50 gallons. In order to dye indiarubber green, take—ammonium chloride, 50 lb.; sulphate of copper, 51 lb.; quicklime, 100 lb.; water, 40 to 50 gallons. Boil for a quarter to half an hour.

"*Other English receipts.*—To dye black, boil a quarter of an hour to half an hour in the following bath: Copper sulphate, 50 lb.; ammonium chloride or ammonia, 50 lb.; quicklime, 50 lb.; water, 50 gallons; or—bisulphate of potash; 50 lb.; sulphate of copper, 25 lb.; water, 50 gallons. For green, boil the rubber for a quarter to half an hour in the following bath :—Sal-ammoniac, 50 lb.; sulphate of copper, 25 lb.; quicklime, 100 lb.; water, 50 gallons. For lilac, boil a quarter to half an hour in—sulphate of potash, 500 lb.; sulphate of copper, 125 lb.; sulphate of indigo, 125 lb.; water, 500 gallons.

"Whatever process is used, care must be taken to guard against using poisonous colours for objects intended to be frequently handled, such as children's playthings, or to be brought in contact with our respiratory organs. Such are those into which copper, lead, mercury, and arsenic enter. In such cases it is absolutely necessary to use harmless colours, such as those in Table XLVIII. We may

TABLE XLVIII.—HARMLESS PIGMENTS THAT MAY BE USED IN COLOURING RUBBER.

Colour.	Pigment.
Blue	Indigo, ultramarine.
White	Non-arsenical zinc oxide.
Red	Cochineal and lakes, archil.
Yellows	Persian berries, quercitron, turmeric, fustic and lakes, yellow wax, chromate of zinc or magnesia.[1]
Green	Guignet's green; mixtures of above yellows and blues.
Black	Carbon in all its forms.
Lilac	Mixtures of ammoniacal cochineal and ultramarine.
Brown	Terra di Sienna and lamp-black.

also mention the eosin lakes. As is known, these beautiful colouring matters are the result of the combination of eosin with oxide of zinc.[2] Added to chromate of zinc, in different proportions, they yield bright colours, which may replace red lead and chrome yellow. Finally, with ultramarine they form more or less intense violets. All these colours perfectly resist light and heat. They may be incorporated in the rubber paste, then submitted to the temperature necessary

[1] Poisonous salts of lead, tin, antimony, and barium are often used in precipitating lakes of all colours; such lakes are of course poisonous, and chromates as a class are far from innocuous.

[2] In Great Britain, at any rate for paint purposes, the eosin is most generally in the form of *eosinate of lead.*

for vulcanisation, without undergoing the least alteration." As to the coloration of ebonite, sufficient details have been given at the end of the chapter devoted to that substance, so that there is no necessity to revert to the subject.

The toxic action of zinc oxide on rubber teats, etc.—To terminate this paragraph, and not to be under the necessity of returning to the question of the toxic substances often entering into technical mixtures, let us recall that Tollens has collected a certain number of facts which prove the unwholesome influence of tubes, teats, ends of sucking-bottles, joints, etc., loaded with a notable quantity of oxide of zinc. He also thinks that the rubber employed in dental surgery is not always exempt from defective composition in this respect. In support of his statement he quotes the composition of a white rubber employed by certain dentists :—

TABLE XLIX.—COMPOSITION OF RUBBER USED BY CERTAIN DENTISTS (TOLLENS).

Substance.	Per cent.
Oxide of zinc	43·96
Chalk	0·62
Oxide of iron	traces
Sulphur	26·60
Rubber	28·82
	100·00

Vermilion also enters sometimes into such mixtures, but this substance is possibly the most innocuous of all mercurial compounds.

Methods of analyses of indiarubber.—No one had taken the trouble to give a scheme for the analysis of either raw rubber or of vulcanised rubber, until Heinzerling in 1883 attempted the undertaking. His work, unfortunately, is not complete; and if he omits certain details, such as the determination of oxidised rubber in commercial raw rubber (an important point), he nevertheless insists on certain analytical processes in the analysis of transformed rubbers which prove absolutely nothing if they remain isolated and not co-ordinated with others. Thus the determination of the density of vulcanised or mineralised rubber, without a qualitative analysis at least, has no signification; a technical rubber may be mixed, not only with cork dust, but also with barytes. The density of the first, therefore, may be as near as possible to the natural rubber, whilst containing a much smaller quantity of real rubber than a second sample of greater density but with a much higher proportion of real rubber. Heinzerling states that it answers very well for determining approximately the quantity of mineral matters which enter into a mixture, but owns that it is not conclusive, as it gives no information as to a mixture in which the rubber has lost a portion of its properties by an addition of substances equal to or lower in density than 1·0, or even when, by these same additions, the mixture has acquired a greater bulk than that of genuine vulcanised rubber. The following additions require special mention: boiled linseed oil, and other fatty derivatives, paraffin, etc., the use of which in this industry tends daily to become greater. It is difficult to discover the presence of one of these bodies by qualitative analysis. As to the exact determination of the quantities used, Heinzerling finds the difficulty insurmountable. E. Donath, in 1887, was engaged in the same kind of work, but more especially in regard to vulcanised rubber. Availing ourselves of the researches of the scientists who have investigated the matter, and completing them when there is a possibility of doing so, we shall attempt to establish as complete a method of general application as the actual state of science will allow. Not that we are the victims of any great illusion, but few of these scientific determinations are made, either in the trade

or in the industry generally. If it be a question of raw materials, the buyer generally trusts to his own experience; he judges the rubber *de visu*, and should he be wrong a hundred times he will not own to it until it is too late. Should he, on the other hand, be free from these preconceived ideas, he would not always have the time to have recourse to the intervention of the chemist, and, before the analysis of a given lot was finished, it would be in the hands of his rivals. As far as finished products are concerned, the buyer trusts to the reputation of such and such a firm in the purchasing of any given article. Analysis is a long and costly process. Why, then, should he resort to it when he knows the skill and the probity of the maker? To the manufacturers who wish to transform the raw material into manufactured articles under such conditions that they may advantageously sustain that pacific but continual struggle without truce and without mercy, which is called competition, whether local or foreign, a method of analysis—as simple and rapid as possible—is of the utmost importance.

Analysis of commercial crude rubber.—In the synthetical Table of the principal varieties of commercial rubber, to be found at the end of Chapter IV., a few columns are devoted to the principal physical properties characteristic of each variety. This summary information certainly has its value, but it is not sufficient to guide and inform the manufacturer exactly as to what uses he can convert any given lot of rubber. What, then, are the principal points on which he must be enlightened? The answer is short and precise.

Points to be determined and elucidated.—1. *Moisture.*—The quantity of interstitial water in the pores of the rubber, and whether it does not exceed the normal quantity. 2. *Extraneous mineral matter.*—The quantity of inert mineral matter, whether incorporated accidentally or intentionally. 3. *Extraneous organic matter.*—The amount of extraneous organic matter of the same origin as the mineral matter. 4. *Extraneous matter introduced by method of coagulation.*—The quantity of foreign bodies, whether organic or inorganic, the presence of which is chiefly due to the methods of coagulation. 5. *Oxidised rubber.*—The quantity of oxidised rubber, that is to say, rubber which has lost the properties indispensable to its industrial use. 6. *Ash.*—The quantity and nature of the ash which a given weight of substance may yield on incineration. 7. *Resistance to strain.*—The total resistance yielded by the sample under a determined strain. 8. *Microscopical examination.*—A microscopial examination may, on the other hand, complete this analysis, and yield information in regard to the origin of the rubber which direct analysis can only with difficulty afford.

Sampling.—The great difficulty in testing rubber lies in getting a fair average sample. The method which appears to us to give the best possible results is as follows: (1) To take different samples from different parts of the inside as well as the outside of the cakes or blocks to be analysed. (2) To shred and roll these sufficiently, and to take from the few samples at different points so as to get a fair average sample.

Determination of interstitial moisture.—This operation is delicate, because rubber, even the purer kinds, always contains in its pores some 5 per cent. of water, which we shall call the normal quantity, which is not eliminated, even by prolonged drying at 100° C. (212° F.). The sample, reduced to as thin a sheet as possible, by passing through cold rolls, is weighed, then laid upon a watch-glass and dried in the hot-air oven between 110° and 120° C. (230° and 248° F.), until it ceases to lose weight. By taking a few precautions, the total interstitial moisture may be thus determined in about two hours.[1] Two watch-glasses, ground so as to form a hermetic joint, and capable of being bound by an indiarubber band, are used. The rolled sheetlets of rubber are placed on one of these glasses, and so taken to the oven. After the lapse of an hour, the sample is taken out along with the glass, and, after being covered with the second glass, the caoutchouc ligature is put in position, and the whole cooled in a desiccator and then weighed. The processs is gone over again until no further loss in weight occurs. The loss in weight P

[1] Gypsum (*Terra alba*) loses its water of crystallisation between these temperatures.—Tr.

constitutes the total moisture. By deducting 5 per cent. of normal water present in every rubber of whatever kind it may be, we then get—

$$\text{Water} = (P - 5 \text{ per cent.}).$$

The sample so dried is put aside for future use.

Determination of inert vegetable and mineral matter.—For the determination of fragments of wood and stones of a certain size, often met with in certain blocks, quantitative analysis is not practicable, and the examination of sections of several blocks, by the naked eye, is sufficient for any practical man however little experienced. It is only the amount of sand, clay, and vegetable débris, so minute as to escape detection *de visu*, that is now in question. Ten grammes of rubber, laminated as described, are dissolved in spirits of turpentine or in benzol at 40° to 55° C. (104° to 131° F.). The insoluble is collected on a filter, washed several times with the same vehicle until no rubber is left on evaporation. The residue is dried and weighed. The difference in weight gives the total organic and inorganic matter in the sample. By incinerating the residue in a suitable manner, the quantities of organic and mineral matters are obtained separately by difference. If, however, only the weight of the mineral matter be required, simple incineration of the rubber in a platinum crucible is sufficient. But to obtain a mineral ash, perfectly exempt from carbon, produced by the incomplete combustion of the organic matter, a few pinches of nitrate of ammonia must be added, with infinite precaution, to the red-hot mass after prolonged ignition, slightly inclining the crucible. The results obtained by this second summary method are not strictly accurate; the total ash would include alum, common salt, etc., from the coagulation process, besides mineral residues originating from the intimate constitution of the rubber itself; the latter may be neglected, unless it be a question of determining by analysis the exact origin of a certain kind of rubber.

Determination of the organic and inorganic matter derived from the process of coagulation.—To determine the total organic, or inorganic, acid, or saline matter in the rubber being analysed, the dried rubber used for the determination of moisture, and the percentage of moisture in which is therefore known, is boiled in a small flask for a long time with distilled water. The substance, after filtration and repeated washing, is dried in the hot-air oven, with the same precautions as formerly, and finally weighed; the loss in weight gives the soluble matter, and this loss P' will be, if we represent the loss in water by $(P - 5)$, the initial weight by C, and finally the weight actually found by C',

$$P' = C - (C' - (P - 5)).$$

A qualitative examination of the wash water, added to the water in which the rubber was first boiled, will give information as to the mixture of acids and salts eliminated.

Determination of the oxidised rubber.—This determination, very important with certain kinds highly charged with this substance so prejudicial to the nerve of the rubber, is made thus: A weight is taken equal to that taken for the estimation of the water, and treated with boiling 90 per cent. alcohol for half an hour. The residue is thrown on a filter, washed repeatedly with boiling water, then placed as formerly in the hot-air oven and dried at 120° C. (248° F.), until it ceases to lose weight. If we represent the oxidised rubber by P'' and the weight found by C'', we get—

$$P'' = C - (C'' - (C' - (P - 5)).$$

The evaporation of the alcohol liquid and its suitable treatment will, moreover, furnish indications as to the nature and, if need be, the quantity of the substances so eliminated.

Analysis of vulcanised rubber. — From the phenomena observed in the study of vulcanised rubber Donath enunciates the following law:—*The value of vulcanised rubber articles is perceptibly proportional to the rubber content, and dependent upon the ratio between rubber and the quantity of sulphur or metallic sulphides used in their vulcanisation.*—Suppose we call (1) the value of the rubber,

V; (2) its percentage of sulphur, S; (3) its percentage of mineral or organic matter, E, we get—

$$V = \frac{100 - (S + E)}{S}.$$

To determine the elements of V, therefore, a simple proximate chemical analysis is sufficient, and it is only in special cases that we have also to examine the elasticity and resistance of the rubber.

Donath's law is too absolute (Dr. Lobry and Van Leent (*Chemiker Zeitung*, 1894, p. 309)): it presupposes the identity in properties of the rubber employed in these different articles—a very doubtful supposition, even if the resins in different quantities and of diverse qualities which accompany natural rubbers of different origin be eliminated. Practice shows that two rubbers prepared from the same raw rubber, the one, however, containing 3 and the other 6 per cent. of sulphur, may be equally good, although, according to Donath's law, the first sample ought to be of double the value of the second.

1. *Specific gravity—Ash.*—The opinion expressed by the generality of specialist writers that the knowledge of the specific gravity of manufactured rubber is a powerful factor in its valuation has already been refuted. A density lower than from 0·926 to 0·948 does not decisively show the good quality of a rubber. Sawdust and cork raspings, far from weighting this substance, on the contrary lighten it, and nevertheless these substances are classed with the most injurious additions. Ten per cent. of vermilion or of calcium fluoride influences the density in quite an opposite direction to that of an equal quantity of talc or magnesia, etc. It is well, however, to know in certain cases the density of the substance to be analysed. It may, up to a certain point, aid in the valuation, but only where the mineral substances added are not vulcanising agents like vermilion, sulphide of antimony, etc., because such agents increase the density much more than talc or other lighter mineral substances, and yet, far from injuring, they almost always improve its quality and increase its durability. To determine the density of a sample of rubber by the picnometer (a modification of the classical specific gravity bottle), the sample is divided into small thin strips of equal length; after being weighed, they are boiled with water in the apparatus, which is first tared empty and then weighed full of water so as to get rid of the air-bells which adhere rather strongly to certain places. Many samples which float on the surface of the water fall to the bottom after the operation. This done, the picnometer is again filled with water to the mark and again weighed; the increase or decrease in weight is obtained by simple calculation. An example will render this simple operation easily understood—

TABLE L.—SHOWING A TYPICAL RESULT IN FINDING DENSITY OF RUBBER, WITH NECESSARY CALCULATION.

Suppose the weight of the empty picnometer to be	10 grammes	} weight of picnometer full, 110 grammes.	
,, ,, water to fill it ,,	100 ,,		
,, ,, rubber ,,	5 ,,		
And finally the weight of the picnometer containing the rubber, and filled with water, to be	111 ,,		

The rubber having therefore replaced the water, has given an increase of 1 gramme. Dividing the absolute weight of the rubber (5 grammes) by the weight of the water displaced, that is to say, 4 grammes, the density of the substance tested will be $\frac{5}{4} = 1·250$. *Heinzerling's approximate method.*—Heinzerling uses a more rapid and simple but less exact method, which should be of use in factories. He prepares a series of test-glasses on feet filled with liquids of gradually and uniformly increasing density. He uses for this purpose various solutions of calcium chloride up to a density of 1·40. As calcium chloride is insoluble in water after that

density has been reached, his density experiments did not go beyond that. He in that way established the following scale :—

TABLE LI.—SCALE OF DENSITIES AND FORMULA OF SALINE SOLUTIONS FOR DETERMINING DENSITY OF RUBBER (HEINZERLING).

Test-Glass on Foot.	Density.	°Twaddell.
1. Distilled water	0	...
2. Water and calcium chloride	1·025	5
3. ,, ,,	1·050	10
4. ,, ,,	1·075	15
5. ,, ,,	1·100	20
6. ,, ,,	1·125	25
7. ,, ,,	1·150	30
8. ,, ,,	1·175	35
9. ,, ,,	1·200	40

He determines the density of rubber by dipping a sample into each test-glass in rotation, and observes, after a little time of contact, when all the air-bells have disappeared from the sections of the sample, in which of the solutions the rubber floats between two liquors without going to the bottom. The specific gravity of the liquid in which it floats is the same as that of the rubber tested. Tests, made in Belgium, on tubes of different quality, gave the following results by the picnometer :—

TABLE LII.—SHOWING INFLUENCE OF PERCENTAGE OF ASH ON DENSITY (HEINZERLING).

	Prime Quality.	Low Quality.
Density	0·99–1·20	1·26–1·52
Ash	2·83–25 per cent.	34·30–38·60 per cent.

The ashes of low qualities consisted chiefly of chalk and the oxides of zinc and iron. This latter oxide dominates in red-coloured tubing. Reinhardt gives the following results :—

TABLE LIII.—SHOWING INFLUENCE OF PERCENTAGE OF ASH ON DENSITY (REINHARDT).

	Sample I.	Sample II.
Density	1·480	1·958
Ash	53·57 per cent.	62·66 per cent.

The ash consisted chiefly of fluor spar and zinc oxide. Donath gives his own analyses—

TABLE LIV.—SHOWING INFLUENCE OF PERCENTAGE OF ASH ON DENSITY (DONATH).

	White Gas Tubes. (*a.*)	Red Tubes of Excellent Quality. (*b.*)	Red Tubes of Average Quality. (*c.*)	Red Balls Half Full. (*d.*)
Density	1·012	1·134	1·089	1·133
Ash	6·62	8·14	11·72	21·86
Predominant substance in the ash	Zinc oxide.	Sb_2O_4	Vermilion.	Vermilion.

The density of the product therefore does not depend solely on the nature and the amount of additional substance, but also upon the method of vulcanisation and the mechanical process by which the mineral substance is incorporated.

Another analysis—

TABLE LV.—SHOWING THE INFLUENCE OF PERCENTAGE OF ASH ON DENSITY (DONATH).

	Indiarubber Sheet or Foil.	
	e.	*f.*
Density	1·566	1·488
Ash	56·08	72·10
Predominant substance in the ash . .	Chalk and gypsum.	Oxide of zinc.

In *f* the ash retained the shape of the small cubes of the cut sample.

N.B.—Rubbers having a greater density than 1·3 should invariably be regarded as defective, because they contain not less than 25 per cent. of mineral matters which lower their value.

2. *Estimation of mineral additions.*—Direct calcination always yields erroneous results (Donath). Thus vermilion in admixture will partially volatilise on calcination,[1] whilst carbonate of lime will decompose. It results from this want of precision that the operation is not always an easy nor a simple one. The following is an approximate method of estimation:—From ½ to 1 gramme of the sample is cut into thin strips and steeped in a solution of ammonium nitrate, and the strips, previously dried, are thrown one after the other into a porcelain crucible lying almost horizontally on the flame; the crucible is, moreover, brought to a red heat before commencing the incineration. If it has been previously ascertained by qualitative analysis that the substance is not very highly charged with lime, the calcined product may be weighed directly; but if the ash is likely to contain much free lime it is moistened with a concentrated solution of ammonium carbonate and heated slightly before weighing. Reinhardt treats the rubber with boiling nitric acid to dissolve organic matter, and, after evaporating the liquid to dryness with hydrochloric acid, he estimates according to the ordinary classical methods the oxides of zinc, calcium, magnesium, etc. This evidently more exact but too long process is not usually necessary: the approximate percentage which is determined from the weight of the suitably prepared ash gives indications which are always sufficient to decide as to the value of the sample examined. Donath found a minimum of 6·62 per cent. ash in a gas tube, and 72·21 per cent. in a "washer." Donath gives the following order of frequency for the different mineral substances added—chalk, oxide of zinc, gypsum, fluor spar, talc. He has never found oxide of iron in appreciable quantity.

Estimation of sulphide of mercury.—Weigh out from ½ to 1 gramme of the sample, reduce to a fine powder by the grater, or cut into small fragments, and treat in a precipitation flask, which will stand heat, with 30 c.c. of ordinary nitric acid, and heat until bright red fumes cease to be disengaged. The hydrocarbide is entirely dissolved, the vermilion remains intact. The clear liquid is decanted after cooling, and the residue washed two or three times with nitric acid. It would not do to immediately wash with water, as long as there remains any hydrocarbide dissolved in the acid; in contact with water it would be precipitated, and become mixed with the mineral residue. The residual sulphide is run into a tared glass vessel, washed with water, dried at 180° C. (212° F.), and weighed. Vermilion can nearly always be detected in a mixture by the bright coralline red colour which it imparts to the rubber. Rubber vulcanised by vermilion is almost always

[1] Genuine vermilion by itself is practically completely volatile, leaving only an infinitesimal ash.—TR.

heavier than water. Donath found 11·72 per cent. in gas tubing, 21·8 per cent. in a half-filled ball. These two samples were excellent quality rubbers which had preserved both elasticity and pliancy for several years. *N.B.—The fresh section of this rubber shows an amount of adhesiveness not met with in rubber vulcanised by any other process.*

Estimation of antimony sulphide.—Rubber of not so deep a red colour, or of a brown red, generally contains antimony sulphide. It is used alone (Unger), but it is now generally replaced by a solution of sulphantimoniate of lime, hyposulphite of lime, and polysulphide of lime. This mixed solution is precipitated by sulphuric acid. The product so obtained is a mixture of golden sulphide of antimony, sulphate of lime, and free sulphur in variable proportions. 1. *Unger's method.*—The best method of estimation is that of Unger: Heat 1·5 gramme of the finely divided sample in a capacious porcelain crucible with 10 grammes of crystallised sodium sulphide, moderate heat until intumescence ceases, and heat gradually to dull redness. After cooling, the residue is extracted from the crucible by distilled water, filtered to separate the charcoal produced by incineration of the organic matter, and the filtered liquid is precipitated by hydrochloric acid (HCl). The antimony sulphide and the sulphur is collected on a double tared filter, dried and gently calcined in a double crucible, until the sulphur is completely dissipated; the weighed residue constitutes the antimony sulphide. 2. *Alternative method.*—The sulphide of antimony and sulphur are dried until of constant weight, a known quantity is taken and converted into Sb_2O_4. 3. *Another method.*—Or, better still, if there be not much antimony sulphide: wash by decantation, passing the wash water through a filter, redissolve the precipitate in ammonium sulphide, with the addition of a little warm ammonia. This liquid is passed through the same small filter which has been used to collect the antimony sulphide carried along during decantation; it contains all the antimony sulphide. It is gently evaporated in a porcelain crucible, and the sulphide finally converted into oxide Sb_2O_5. In an excellent quality rubber, used in making laces and thread, 11·80 per cent. of antimony sulphide was found. Articles vulcanised by antimony sulphide, recognisable by their brown brick-red colour, and often sold under the name of supple rubber, are generally regarded as of excellent quality. They not only exhibit remarkable suppleness and elasticity, but are very durable. Samples preserved for eight years were intact in regard to quality. But these are precisely the dearest kinds of rubber.

Estimation of the total sulphur—Donath's original method.—This is an element important to estimate. Donath firstly estimated it (in this instance rubber not loaded with any sulphate, such as gypsum or barytes) thus:—He took a gramme of the substance finely divided either by rasp or file, and heated with nitric acid until no more bright red fumes were evolved; he evaporated the solution to dryness with hydrochloric acid and chlorate of potash, dissolved the residue in hot water, acidulated with hydrochloric acid, and he precipitated in the filtrate the sulphuric acid as barium sulphate. The organic bodies from the oxidation of the rubber are partially precipitated by dilution, and render filtration difficult and tedious. *Donath's improved process.*—Donath, therefore, adopted Eschka's process for estimating sulphur in fuel, but, owing to the difficult combustion of rubber, he added to his oxidising mixture, magnesium nitrate, in addition to ammonium nitrate. He intimately mixes—

TABLE LVI.—DONATH'S MIXTURE FOR CALCINING RUBBER FOR ASH DETERMINATION.

Finely divided rubber	0·5 to 1 gramme.
Calcined magnesia	1 gramme.
Nitrate of magnesia	1 ,,
Nitrate of ammonia	1 ,,
Carbonate of soda	1 ,,

He places this mixture in a tall narrow crucible, and covers it with a layer of the above mixture. The crucible, fixed obliquely, almost flat, is at first heated on the upper portion, then gradually towards the bottom, and the heating continued to redness. Its perfectly white contents are extracted, with about 300 grammes of hot water, the solution filtered, acidulated by hydrochloric acid, and precipitated by barium chloride. By this method there is estimated, along with the sulphur used in vulcanisation, that present as gypsum or barytes, etc. To get the vulcanisation sulphur, the latter substances must be estimated. *Unger's method.*—Total sulphur is determined by fusing about 0·5 gramme of the sample divided into 100 pieces, with a mixture of 12 per cent. of copper oxide and 2 grammes of sodic carbonate. This method is likewise to be recommended.

Estimation of vulcanisation sulphur only—Reinhardt's process.—The sample is introduced into a hard glass tube, closed at one end and enlarged about its middle. The open extremity is drawn out over the blowpipe and closed. The portion of the tube containing the rubber is heated over the naked flame, the vulcanisation sulphur distils and condenses with the other dry distillation products in the blown-out portion of the tube. The sulphur is then estimated by one of the known processes. *Precaution* :—A portion of the vulcanisation sulphur may very well be retained in the state of sulphite by the oxide of zinc, or by the chalk, and thus escape distillation and estimation. No method for direct determination of vulcanisation sulphur is known and only a more or less approximate estimation can be made of the proportion in certain cases by means of an indirect calculation. The author [1] obtained the following results by Eschka's process :—

TABLE LVII.—RESULTS OBTAINED IN CALCINING RUBBER BY ESCHKA'S PROCESS FOR DETERMINATION OF MINERAL INORGANIC INGREDIENTS.

Rubber for stoppers	1.	Ash	25·85 per cent.	Consisting principally of chalk, magnesia, and silica.	
		Sulphur	6·47 ,,		
	2.	Ash	23·78 ,,	...	
		Sulphur	7·21 ,,	...	
Rubber for joints		Ash	50·08 ,,	Consisting of zinc oxide and chalk.	
		Sulphur	5·48 ,,		
Rubbers (two) containing vermilion		Vermilion		11·72 per cent.	21·86 per cent.
		Sulphur calculated on 6 per cent. of vermilion		1·61 ,,	3·01 ,,
		Total sulphur found directly		1·90 ,,	3·28 ,,

From the two last analyses, these two rubbers appear to have been vulcanised by vermilion alone, which would accord with the function of vermilion as a vulcanisation agent. This is a very serious argument against the theory of chemical combination between sulphur and rubber through the medium of metallic sulphides. Because, by dissolving with nitric acid, the rubber gives up all its vermilion as such, and consequently also the total of its sulphur, which could not be the case if a portion of the sulphur had entered into chemical combination with the rubber. By the following process we can ascertain the amount of vulcanisation sulphur, roughly it is true, but near enough in most cases. One gramme of rubber, of which the percentage of sulphur is known, is cut up and boiled for a certain time, half hour to one hour, with caustic potash of average concentration (Sp.g.) = 1·2. The sample to be tested is treated in exactly the same manner at the same time, The liquors are decanted and brought to the same degree of concentration, and 1 c.c. of a solution of lead acetate is added to each. The respective amount of sulphur present in each is judged from the relative abundance of the black precipitate in the two glasses. Rubbers vulcanised by metallic sulphides cannot, of course, be so tested. The two samples containing vermilion, the analyses of which are given above, only yielded, when acetate of lead was added to their alkaline

[1] ? Reinhardt.—TR.

decoction, a faint brownish tint—a fact which supports what has been said in regard to vulcanisation by vermilion alone.

Estimation of ammonia.—This substance is only present accidentally in the composition of trade mixtures when it is required to prepare a porous and spongy substance. Incineration eliminates it totally. It may be detected by treating a fragment of the substance to be tested with a little quicklime. Ammoniacal salts are detected by the disengagement of ammonia, the smell of which is characteristic. It is easily estimated, quantitatively, by Will and Warrentrap's process.

Examination of the action of concentrated alkaline solutions and solvents.—It is often necessary, in testing rubber, to treat it with concentrated alkaline solutions and solvents. If the rubber contains a fat, resin, or paraffin, all of which approaching rubber in density and the presence of which cannot be detected by taking the density, recourse is had to a solvent like spirits of turpentine, or to carbon sulphide to which 5 per cent. of alcohol has been added. By digesting the finely divided sample for several hours in one of these solutions, heated from 60° to 70° C. (140° to 158° F.), fatty substances unattacked by vulcanisation, resins, and paraffin dissolve before the rubber, which remains as a residue. If the solvent be evaporated after sufficient digestion, a residue is obtained containing, along with a small quantity of dissolved rubber, the whole of the above-named substances. When the residue is treated with caustic soda solution, the resins and fats are saponified, leaving a residue of unsaponifiable paraffin. A more exhaustive examination of the fats is hardly possible, and, moreover, is only of secondary interest. Again, paraffin may be detected in the product evaporated as above, by treating it with benzol or carbon disulphide, in which it dissolves more rapidly than fats and resins.

In spite of the drawbacks which will always exist in methods of separation of substances of the character of those by which rubber is sophisticated, it will be seen from the following results of an analysis of a sample of known composition that information of real value to the manufacturer is obtained by what is called the solution method of indiarubber analysis.

The sample, a grey vulcanised rubber, was made from the following mixing :—

TABLE LVIII.—MIXTURE USED IN MAKING TYPICAL VULCANISED RUBBER FOR ANALYSIS (GRIMSHAW).

Native rubber	8 lb.	= 13·3 per cent.
Recovered rubber (para No. 12)	3 ,,	= 5·0 ,,
,, ,,	12 ,,	= 20·0 ,,
Zinc oxide	8 ,,	
Whiting	20 ,,	
Magnesia	2 ,,	= 59·2 ,,
Litharge	5 ,,	
Lime	½ ,,	
Sulphur	1½ ,,	= 2·5 ,,
	60	100·0

TABLE LIX.—CLASSIFICATION OF INGREDIENTS IN TABLE LVIII.

(a.)	Per cent.
Indiarubber	31·8
Mineral matter	65·7
Sulphur	2·5
	100·0

Turning to the percentage composition of the sample as determined by analysis, we get—

TABLE LX.—RESULT OF ANALYSIS OF VULCANISED MIXTURE OF TABLES LVIII. AND LIX.

(b.)	Per cent.
Indiarubber	22·65
Resins, oils, and bituminous matter . . .	8·97
Mineral matter	65·9
Sulphur	2·48
	100·00

The analysis as calculated from the mixing is really as follows:—

TABLE LXI.—ANALYSIS CALCULATED FROM ABOVE TABLES.

(c.)	Per cent.
Indiarubber	27·7
Resins	4·10
Mineral matter	65·70
Sulphur	2·5
	100·00

Comparing the found (*b*) with the calculated (*c*) there is 4·87 per cent. more resins, etc., shown by the analysis than originally existed in the mixing. Some of this discrepancy is no doubt due to the want of absolute accuracy in the process, but even the highest grades of rubber are by the heat of friction during mixing, and action of the ingredients during vulcanisation subject to the formation of a small percentage of soluble resinous and bituminous bodies as shown in the figures just discussed.

FIG. 91.—Apparatus for elongation experiments.

Testing by mechanical strain.—In certain cases it is desirable to make a mechanical resistance test—traction, compression, bending, and breaking strain. In the special chapter the physical and chemical properties of vulcanised rubber, the interesting work of Stewart on the resistance to elongation and compression of vulcanised rubber has been summarised. As the apparatus which he used for these elongation experiments was very simple, and within reach of every manufacturer, it will be useful to give an illustration of it (Fig. 91), which indicates the arrangement which the shape of the bands tested allowed to be adopted, so as to avoid, as far as possible, fraying the surface of the rubber and the rounded sections; the iron hooks between which the band is caught are polished. One of these hooks is fixed to a solid crosspiece, the other carries a plate to support the weights. The lower plate and its hook are balanced so as together to weigh 1 kilogramme (2·2 lb.), the weight of the rubber itself is quite neglectable. Under a certain load the indiarubber band is at first round, then, elongating itself, its two sides become straight and parallel. Two datum lines have to be marked on each side of the ring giving the exact length of a portion of the band comprised between the two hooks. This is done by pressing the unloaded ring between two rules until the two sides touch, and drawing with ink two fine marks, starting from a given point, which is the initial length of the band being

tested. By working so, and measuring, after each addition of weight, the vertical distance between the two divisions, all error arising out of the friction of the rubber, or its lamination on the hooks which sustain it, is avoided. During the whole course of the experiments the temperature ought to be as constant as possible, varying between + 14° and + 16° C. (57·2° and 60·8 F.).

Stewart also used a more complicated apparatus to determine the breaking strain, consisting of an English balance for test springs of every nature at the arsenal (Stores Department) of the Belgian Railways at Malines. A A are the bands to be tested, previously well measured. A single piece, or several pieces, with intercalated iron plates, were used according to their height. B is an iron screw, turning in a bronze nut, fixed on the cast-iron framework of the apparatus; it is terminated (1) by a large fly-wheel, with six arms, the circumference of the felly of which is divided into thirty-six equal parts; and (2) by a round head

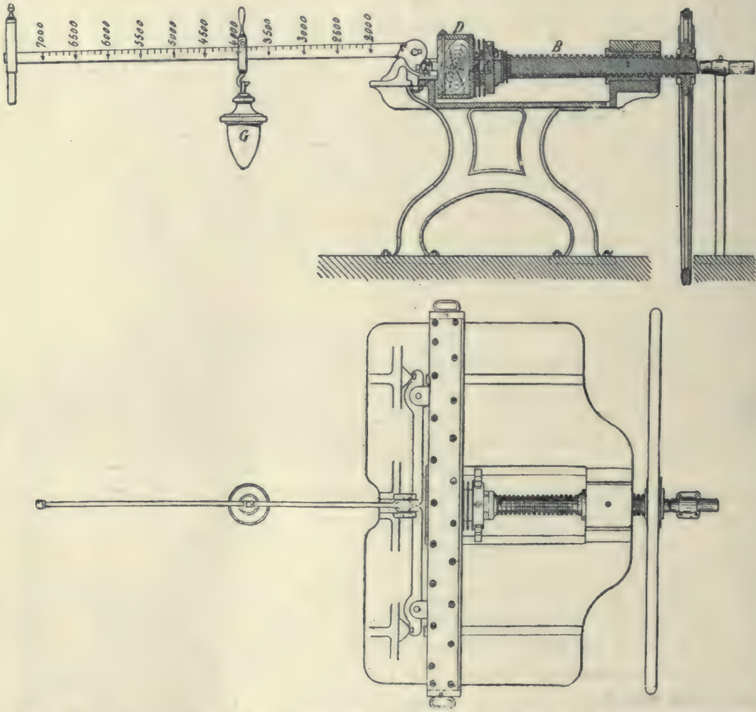


Fig. 92.—Apparatus for determining the breaking strain of indiarubber bands.

which advances without turning, thanks to two claws, C C, sliding on the framework. The bands are held between this head of the screw and a strong wooden crosspiece D covered with iron plate. This latter, receiving in its centre all the effort of pressure, transmits it by means of the two levers E E, mounted on steel knives, to the large elbow lever F, the large arm of which carries two different running weights and two corresponding graduations. One of the running weights weighs 10·4 kilogrammes (22·88 lb.), and allows a force of 1500 to 3300 kilogrammes (3300 to 7260 lb.) being produced; the other, G, weighs 32·2 kilogrammes (70·84 lb.), and allows of pressures on the crosspiece varying between 2100 and 7000 kilogrammes (4420 and 15,400 lb.) being measured. A great difficulty was encountered in measuring exactly the thickness of the reduced rubber; to surmount it with the greatest precision possible. Stewart counted the number of divisions through which the fly-wheel was turned, and deduced from the path of the screw the amount of the compression the bands underwent, so that

the apparatus showed each time in its position of equilibrium the large lever raised to the horizontal position marked on a fixed index. The screw, 37 threads on a path of 470 millimetres (18·471 inches); the thread was therefore 12·7 millimetres (say ½ inch), and for one thirty-sixth or one division of the fly-wheel the head advanced 0·353 millimetre (say $\frac{1}{72}$nd of an inch). The apparatus so transformed into a gigantic spherometer, was precise enough to estimate the depression at each weighing to about a division, *i.e.*, with an approximation of 3 to 4 tenths of a millimetre.

Resistance to bending.—For tests of resistance to bending to the point of rupture, no special apparatus is in existence. Heinzerling thinks that it would be possible to test rubber for this, as is commonly done with leather, provided that in adapting the rubber bands to the bob of a pendulum a sufficient to-and-fro movement could be produced to cause rupture. In fact, if the manner in which the samples behave to the point of rupture be observed simultaneously with the speed of the pendulum, sufficient data should be got to appreciate the resistance of the object to a bending strain up to the point of rupture. It must not be forgotten, if exact comparative results be desired, to attach the samples to the pendulum so that the bending is always and in every sense produced under the same angle.

Resistance to heat.—According to Dr. C. A. Lobry and F. H. Van Leent (*loc. cit.*), *the British navy has used for a long time a very simple method for testing the value of indiarubber.* The objects are submitted to a dry heat of about 135° C. (275° F.), and to moist heat in water of about 170° C. (338° F.). Heat acts very differently on pure good quality rubber from what it does upon inferior kinds containing a greater or less proportion of natural resin, or on the qualities mixed with spurious rubber and other adulterants. Para, pure or mineralised, and suitably vulcanised, resists this test for two to four hours without a too marked destruction of its original qualities. But inferior sorts present little or no resistance at all to the action of heat, become brittle, tacky, lose their elasticity, etc. The loss of weight of rubbers exposed in thin sheets for one or three hours to a dry heat of 135° C. (275° F.) hardly reaches the figures shown below in the case of good qualities—

TABLE LXII.—LOSS SUSTAINED BY RUBBERS HEATED FOR 5 HOURS TO DRY HEAT OF 135° C. (275° F.).

Name of Rubber.	Loss after One Hour.	Loss after Three Hours.
	Per cent.	Per cent.
Para	0·15	0·25
Mozambique	0·20	1·30
Borneo	1·70	3·90

Kissling's comparative method of analysis.—Kissling in his determination of commercial vulcanised rubber, looks at the matter from quite a special point of view. After an impartial résumé of existing literature, he claims that in the analysis of vulcanised and manufactured rubber the uses to which the object is to be put ought to be taken into consideration. A joint for water pipes ought to have different properties and a different composition from a gas tube or the lining of a manhole intended to resist the action of excessive pressure. A pump valve to resist the action of corrosive mineral acids should not have the same composition as one which has to remain in prolonged contact with oil. Unfortunately there is little agreement in the proportions of rubber indicated as required for each special manufacture. As there is not, according to Kissling, a simple and practical method for determining in an absolute manner the quantity of rubber present in vulcanised rubber, as the determination of the ash alone proves nothing, and it has been already shown how the methods of determining sulphur in its different conditions are not in any way more decisive, it was deemed well to rest content with a simple comparative analysis of the ash of the

substances soluble in one or two appropriate solvents, and then to expose to a temperature of 110° C. (230° F.) for forty-eight hours the types chosen for the manufacture of the same kinds of articles, whether they came from one factory or from another. He then examined their suppleness and elasticity, and finished by a test of resistance to rupture. In the Table LXIII. Kissling has condensed the analytical results of twenty-nine tests according to his method.

TABLE LXIII.—COMPARATIVE TECHNICAL ANALYSIS AND VALUATION OF VULCANISED RUBBER WARES ACCORDING TO KISSLING.

Consecutive Number of Samples.	Nature of the Ware Manufactured.	From Factory No.	Price per Kilo. in Marks = 1·25 Francs.	Soluble in Carbon Disulphide.	Soluble in Ether.	Ash.	Condition after being heated to 110° C. (230° F.) for 48 Hours.	Coefficient of Resistance.
				Per Cent.	Per Cent.	Per Cent.		
1	Steam pipe joints.	I.	4·20	8·76	1·78	61·04	Very hard and very brittle.	9
2	,,	I.	4	8·74	0·74	61·08	,,	9
3	,,	I.	3·80	7·82	1·94	59·50	,,	...
4	,,	I.	3·70	5·28	1·18	62·66	,,	...
5	,,	I.	3	9·96	0·73	63·78	,,	9
6	,,	I.	3·30	6·93	1·45	61·42	,,	9
7	,,	I.	3·60	7·56	0·88	59·64	Rather hard, very brittle.	8
8	,,	II.	...	4·38	1·04	64	Hard but not brittle.	4
9	,,	II.	...	7·60	1·18	66·84	Hard and brittle.	7
10	,,	III.	1·93	4·82	0·34	72	Very hard and very brittle.	9
11	,,	III.	1·93	5·52	0·32	70·8	...	...
12	,,	III.	2·53	5·64	0·28	66·64	Hard and brittle.	7
13	,,	III.	3	17·12	0·44	60·36	Very hard and exceedingly brittle.	10
14	,,	IV.	5	9·36	0·44	65·56	Very hard and very brittle.	9
15	,,	V.	4·40	16·30	0·32	60·52	Very hard and exceedingly brittle.	15
16	,,	VI.	3·50	9·80	0·08	62·16	Very hard and very brittle.	3
17	,,	VII.	5·30	6·30	3·06	48·32	Hard but elastic.	8
18	,,	VII.	4	8·44	0·26	56·60	Very hard and rather brittle.	5
19	,,	VII.	5·30	7·30	1·80	49·52	Very hard and slightly brittle.	8
20	,,	VII.	4	9·32	0·38	35·12	Very hard and rather brittle.	3–4
21	Water pipe joints.	III.	14·04	5·20	0·44	54·72	Rather brittle, slightly elastic.	2
22	,,	VIII.	10·18	8·42	1·24	55·20	Rather soft, slightly elastic.	5
23	,,	IV.	11·55	7·78	3·62	63·04	Hard and rather brittle.	1
24	Rubbers of different kinds and quality.	VII.	17·60	6·66	2·04	2·16	Quite soft, very elastic.	2
25	,,	,,	10·60	4·70	3·14	2·2	Quite soft, rather elastic.	2–3
26	,,	,,	8·80	7·74	1·10	32·40	Slightly hard but elastic.	3–4
27	,,	,,	6·64	6·24	1·22	55·10	Rather hard but slightly elastic.	5
28	,,	,,	4·44	7·10	0·92	35·44	Slightly hard but elastic.	*id.*
29	Rubber for lining canvas pipes.	VIII.	4·44	3·88	1·10	39·48	*id.*	*id.*

Correlation of ash and price of rubber.—It results undeniably from an attentive examination of these figures, that there is always a correlation between the price demanded and the total ash. That is readily understood. But this correlation cannot be at all absolute, because not only does the price vary from one article to another, but vulcanised rubber goods do not consist solely of rubber, sulphur and other mineral additions, but often, in the case of floating articles, that is to say approaching nearer to the destiny of normal vulcanised rubber, organic matter, cork, sawdust, etc., are also incorporated. The real deduction to be drawn from the above Table is that more than 50 per cent. of ash cannot but be very prejudicial to the preservation of the manufactured article. It is better to buy rather dear goods than to acquire a bad article because it is cheap. But here again reservations must be made. Samples 21, 22, 23, water pipes from three

different factories, show clearly that No. 22 is decidedly the best, although much the cheapest. Kissling examines the price and qualities of Nos. 24, 25, 26, 27, and 28, designed by the same manufacturer, as goods of different qualities. Mineral substances, and possibly also organic bodies, have evidently not been added to Nos. 24 and 25; they resist a temperature of 118° C. (230° F.) admirably, but their selling price is too high. No. 24 was made with Para rubber, No. 25 with a lower class rubber to which combustible matter has been added. Nos. 26 and 27 seem to contain mineral additions only, whilst No. 28, the price of which is low, in spite of so low a percentage of ash as 35, certainly indicates admixture with organic matter such as rubber waste, reclaimed or otherwise. It shows itself to be more resistant to a temperature of 110° C. (230° F.) than No. 27 of a higher price. In regard to the first experiments, Nos. 1 to 20, on rubber for joints, if we compare the numbers costed at the lowest price with those the price of which would indicate a greater richness in rubber, it must be concluded that the cheapest only contain but relatively small percentages of sound rubber, smaller even than that indicated by the analytical data, if the richness in rubber be taken by difference.

Henriques' results.—The beautiful investigations of *Dr. Rob. Henriques*, published under the title "Contributions to the Analysis of Manufactured Rubber" (*Chemiker Zeitung*, 1892, pp. 1515, 1623, 1644; 1893, pp. 644, 807; and 1894, pp. 411, 442), cannot be overlooked. The method of analysis adopted is, moreover, the starting-point of a rational method for detecting and valuing indiarubber substitutes, which play such an important rôle in the rubber industry, and the influence of which is almost always so injurious to the durability of the goods. (See under Rubber Substitutes.)

Heinzerling and Pahl's method ("*Annals of the Society for the Advancement of Industrial Science*, Berlin, 1891–92") *for determining the mineral and organic substances on the industrial value of the vulcanised rubber with which they are incorporated.*—Struck with the almost insurmountable difficulties encountered in the exact quantitative determination of each of the substances which enter into the composition of vulcanised rubber, Heinzerling and Pahl have attempted to get over the difficulty, and in a series of very elaborate and detailed investigations studied the effect of the principal products most frequently added to rubber, on its durability, resistance, elasticity, and dielectric properties. Unable to follow the usual method in the choice of samples of a determinate composition coming within the scope of their researches, since (1) direct analysis is almost impossible, especially for the quantitative determination of the organic substances, other than rubber; and (2) manufacturers generally being unwilling to divulge the little secrets of their special manufacture, these two chemists had typical samples made from their data of definite proportions, varying in this way at will the total amount of the substances incorporated so as to study more exhaustively the manner in which each of them behaved.

Inorganic and organic substances incorporated.—Besides sulphur and antimony sulphide—the principal vulcanising agents used,—the authors incorporated the following inorganic substances:—The oxides of zinc and lead, chalk, caustic lime, calcined magnesia, calcium fluoride; and the following organic bodies: rubber substitutes, oils vulcanised by free sulphur, and by sulphur chloride in the cold, paraffin, rosin, or colophony, terebenthine (turpentine),[1] asphaltum, reclaimed rubber powder, and finally glycerine. Ten per cent. of free sulphur was added as a vulcanising agent to all the supple substances thus obtained, with the exception of those containing antimony sulphide, and those already treated by sulphur chloride in the cold; a small addition of sulphur was made to the supple substances already containing antimony sulphide, and all submitted for one hour to vulcanisation at a temperature of 135° to 138° C. (275° to 280°·4 F.), under a pressure of 3 to 3½ atmospheres. The special articles called technical were made in one of the principal manufactories of Northern Germany in the usual proportions, which

[1] Possibly Venice turpentine or turpentine oleo-resin. Spirits of turpentine in this country is often termed "turpentine." Hence much confusion with the oleo-resins.—Tr.

the managing director with great courtesy communicated to the authors of this investigation. The experiments on ebonite were less numerous; the substances added in this manufacture are necessarily more restricted, this branch of the manufacture being of itself less important. Two kinds of tests were made, the one based on chemical action, the other on physical and mechanical action.

Chemical tests.—The chemical tests were made from the point of view of the substances with which rubber most often comes in contact. These are—1. *Sulphuric acid.*—(This acid was chosen because its corrosive action has the greatest effect on rubber, with the exception of nitric acid, which destroys it.) 2. *Acetic acid.*—(This is the organic acid with the most characteristic energy; it, moreover, is the one which comes most often in contact with rubber.) 3. *Soda lye and ammonia.*—(Both very often come in contact with rubber.) 4. *Colza oil.* 5. *Mineral lubricating oil*, as well as these oils mixed with tallow in definite proportions. These substances frequently exert a destructive action on pump, etc., valves, upon pipe joints, etc. 6. *Coal gas.*—(We have already shown the effect of this gas on rubber tubing.) 7. *Physical tests.*—The physical and mechanical tests were made with the object of determining—

1. The modulus of load (*module de charge*).[1] 2. The coefficient of resistance. 3. The limit of elasticity. 4. The modifications in shape under the influence of strong pressure. 5. The modifications in shape under the influence of repeated blows. 6. The effect of prolonged heat. 7. The variation in the insulating power.

All the samples were submitted to the following tests :—

1. *Sulphuric acid test.*—In a solution of sulphuric acid of specific gravity 1·1562 (say 31° Twaddell), which is equivalent to 27·5 per cent. H_2SO_4, there were macerated after previous weighing in the cold the types I. to XVIII. for twenty days, the types XIX. to XXXII. for ten days. Taken out of the steep and conveniently dried, they were again weighed, care being taken to note the modifications of the normal texture which might be presented.

2. *Acetic acid test.*—The acetic acid used had a density of 1·0584 (11°·68 Twaddell) = 46·5 per cent. $C_2H_4O_2$. Contact in the cold only lasted three days, the action of the acid manifesting itself much more rapidly.

3. *Soda lye and ammonia test.*—Soda lye, of specific gravity 1·3084 (say 62° Twaddell), equivalent to 21·5 per cent. of NaHO, was left in contact for three days. Not only was the weight before and after the operation taken, but also the initial and final densities of the samples tested, and the same was done in the case of the acetic acid and ammonia tests. The ammonia used (specific gravity 0·9775, equivalent to 6 per cent. NH_3) was left in contact for four days.

Drying the samples after the tests.—The samples Nos. I. to XVIII. were washed and dried for six hours at a temperature of 100° C. (212° F.). Nos. XIX. to XXXII. were exposed when they came out of the bath for forty-eight hours to the open air, and then dried for half an hour at 100° C. (212° F.).

4. *Colza oil test.*—The colza oil had a density of 0·9102.[2] After five days' contact, the volume of the sample was determined before and after the experiment, as well as in the case of the two following tests.

5. *Lubricating mineral oil.*—Density = 0·8991, five days of contact. 5*a*. *Mixture of* 90 *per cent. mineral oil and* 10 *per cent. tallow* was put in contact with the samples for five days at a temperature of 100° C. (212° F.). 6. *Coal gas test.*—In the test with coal gas, the authors placed the sample in the gas pipe between the burner and the tap; the jet was lit, the experiment lasted twenty consecutive days, so that the sample was in constant contact with the gaseous current. The determinations were made by weighing. 7. *Physical tests.*—For alterations in volume, the micrometer was used so as to determine alterations to the extent of $\frac{1}{100}$ of a millimetre. To obtain the modulus of elasticity and the limit of elasticity, etc., use was made of a special apparatus, with more than one

[1] ? Modulus of elasticity.—Tr.

[2] If this gravity were taken at the ordinary temperature, it is remarkably low for pure colza oil.

point of resemblance to the apparatus described by M. Stewart. *Dimensions of samples tested—Alterations in shape under pressure.*—The samples had each a superficies of 0·02 metre long, 0·005 metre wide, and 0·002 metre thick. The alterations in shape under great pressure were studied with the apparatus used to test building materials in the Swiss Federal Polytechnic. Each compression equivalent to 4900 kilogrammes on a sample of 1·2 centimetre for one minute; the variable thickness of the sample was controlled before and after each test by the micrometer in every direction, and it could thus easily be determined whether the deformation took place uniformly in all directions. As the edges were generally more swollen than the centre, the thickness of the centre, of the sides, and the distance between the two furthest sides were taken. The alterations in shape under the action of repeated blows were made with the apparatus of the Zurich Polytechnic. One square centimetre of a thickness determined beforehand was put under the action of a hammer of 2 kilogrammes in weight (say 4·4 lb.), with a fall of 0·25 metre (say 10 inches), and underwent fifty blows each time. Maximum compression for one minute, 4900 kilogrammes (10,780 lb.). The deformation was not uniform as in the preceding, but showed excentric undulation; they were measured as in the foregoing. The deformation undergone by energetic compression is shown in A, Fig. 93, and in B that undergone under the action of fifty repeated blows.

TABLE LXIV.—COMPARATIVE TRIAL OF TWO SAMPLES OF INDIARUBBER, UNDER STRONG PRESSURE, TO DETERMINE ALTERATION IN SHAPE.

Type.	Initial Thickness.	Thickness of the Extreme Sides after the Test.	Thickness of the Centre.	Displacement of the Furthest Edges.
	Millimetres.	Millimetres.	Millimetres.	Millimetres.
I. . . .	0·95	1·18	0·93	9·00
III. . . .	1·08	1·16	1·01	8·25

No. I. is therefore more resistant than No. III.

TABLE LXV.—RESULTS OF TEST OF TWO SAMPLES UNDER REPEATED BLOWS OF THE HAMMER TO DETERMINE ALTERATION IN SHAPE.

Type.	Initial Thickness.	Thickness of the Extreme Sides after the Test.	Thickness of the Centre.	Displacement of the Furthest Edges.
	Millimetres.	Millimetres.	Millimetres.	Millimetres.
I. . . .	0·95	1·54	0·71	2·75
III. . . .	1·10	1·40	0·90	5·00

No. I. therefore does not stand repeated blows of the hammer so well.

Action of heat.—To test the action of prolonged heat the samples were placed in an oven with a glass door. Heat was applied slowly, so as to get an increase of temperature of 10° C. (18° F.) every half-hour on each occasion. All the accidents which might happen could thus be observed until the final temperature, *i.e.* 150° C. (302° F.), was reached.

Electrical resistance test.—Finally, Weber's electrometer (see Mascart's *Manuel d'Électricité Statique*) was used to determine the variations in the insulating power of the samples. Previous to the test they were placed in a drying oven for half an hour, to remove all traces of moisture. The electrometer at rest marked 500° charged before each test, the needle oscillated upon 260°. From time to time the apparatus was verified to make any necessary corrections. The test was made during the day at a temperature of 12° C.

Remarks on Heinzerling and Pahl's experiments.—It is unnecessary to follow the deductions which Heinzerling and Pahl draw from each of their experiments. The Tables and their indications are sufficient, and readers can themselves draw the appropriate deduction from the facts given. Attention is drawn to the experiments on commercial articles, as delivered by the factory, Table B, in which three species of vulcanising agents, S. metal, pasta (paste), and mixture, have replaced sulphur, in whole or in part, as a vulcanising agent. These products, the composition of which the vendors always keep secret, yield, in the majority of cases, inferior products, the defects of which only become manifest after a certain time. Heinzerling and Pahl tried to ascertain the composition of these three bodies, and they think they recognised—1. Sulphur and the different compounds of ultramarine blue. 2. Paraffin, or a resin to which rubber waste has been added, the whole dissolved in spirits of turpentine, and mixed with plaster, lime, and magnesia. 3. Terebenthine (spirits of turpentine), acting as a vehicle for the regenerated rubber.

The conclusions of this long and important work are :—

1. All *organic and mineral substances* added to supple rubber *diminish its elasticity.* Ten per cent. of sulphur as a vulcanising agent gives the best results so far as elasticity is concerned. On the other hand, *certain organic additions,* such as terebenthine, colophony, bitumen, as well as certain mineral additions, such as mercury sulphide, slaked lime, far from injuring the elasticity, sometimes even accentuate it. 2. The modulus of load (*module de charge*) is increased in

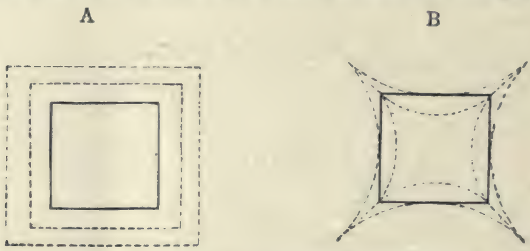


FIG. 93.—Deformation of pressed rubber.

supple rubber by the addition to a certain extent of bitumen, chalk, fluor spar, oxide of zinc, and especially calcined magnesia. The modulus of ebonite is increased by the addition of mercury sulphide, as well as by more prolonged vulcanisation and a greater dose of sulphur. All other mineral additions, lead oxide, slaked lime, and all organic additions, with exception of bitumen in small quantities, can only diminish the modulus of elasticity of ebonite. 3. Mineral additions, such as zinc oxide, lead oxide, chalk, magnesia, slaked lime, bitumen, and glycerine, accentuate the coefficient of electrical resistance of pliant indiarubber. The coefficient becomes much higher in ebonite by the use of a large quantity of bitumen, terebenthine, and rosin, to which lime or magnesia has been added, so long as certain limits are not exceeded. It is the same with vermilion. But the tensile strength of rubber is perceptibly diminished by the intervention of vulcanised oils, turpentine, and paraffin. 4. Pure rubber, containing sulphur, has wrongly been considered as the best insulator : a whole series of mixtures of rubber with certain metallic oxides, zinc oxide, slaked lime, calcined magnesia (in small proportion), antimony sulphide, as well as all the organic additions commonly used ; oils vulcanised by sulphur, those vulcanised in the cold by sulphur chloride (in very moderate proportions), terebenthine, rosin, paraffin, yield, so far as insulating power is concerned, a far better result than pure vulcanised rubber. The insulating power of pliant rubber containing paraffin is the greatest. Vermilion and lead oxide, on the other hand, diminish the dielectric properties of rubber. It is the same with an excess of magnesia. Rubber, vulcanised in the cold, gives the worst results in this respect.

5. All mixtures containing organic additions give off fumes if heated to 130° to 150° C. (266° to 302° F.); such a mixture is therefore to be avoided if the rubber is liable to be exposed to a rather high temperature. The other mixtures generally behave well in this respect.

6. All the mixtures containing chalk, fluor spar, lead oxide, zinc oxide, are strongly acted on by sulphuric acid, as well as by acetic acid, and the weight regularly increases, either because there is formation of insoluble salts, like sulphate of lime, or also of basic salts (basic acetates of zinc and lead). The destructive action of oils is diminished, especially by the addition of zinc oxide and lead oxide. The other inorganic substances added are less efficacious. Alkalies and coal gas do not alter the different mixtures studied to such an extent as to enable any definite conclusion to be drawn. Finally, the organic additions employed all tend to preserve the substance, more or less, from the corrosive action of acids.

7. The generality of rubber compounds which have been mixed with mineral matters harden and become brittle after a more or less prolonged period of storage. They are then less resistant to mechanical strains. So far as insulating capacity is concerned, they do not appear to suffer any loss.

8. Ebonite has not such an extensive use as supple rubber. It is, however, used in making chemical apparatus and in the manufacture of dielectrics. In the first case it should not contain mineral additions. In the second case it gains by being associated with rosin and paraffin.

In order to terminate this investigation of the methods of analysis adopted, the following are the requirements to be exacted from manufactured rubber, according to Dr. Lobry de Bruyn's specifications (*Chem. Zeitung*, 1894, p. 329).

The tests to which it should be submitted are—

1. *The loss in weight on extraction with alcoholic potash.*—This weight should not exceed 8 per cent. of the organic substance (deduction made for ash and sulphur). The experiment is made on 5 grammes of rubber reduced to a thin sheet; it is heated for six hours in a vessel attached to a reflux condenser, with 50 cubic centimetres of a 6 per cent. solution of pure caustic soda in 96 per cent. alcohol. The alcoholic extract should not contain anything more than sulphur and resins; no soaps. The loss of weight is determined by washing the extraction residue, letting it stand for twenty-four hours in water, collecting and drying on a tared filter at 100° C.

2. *The effect of dry heat.*—Two grammes of the sample to be tested, cut into thin strips, are heated in an oven to 135° C. (275° F.) for two hours. After this treatment, the rubber ought to have maintained all its original properties intact. It ought to have lost, at the most, 1½ per cent. in weight.

3. *The effect of superheated water* (*under pressure*).—A piece of known weight is heated for four hours, at a temperature of 170° C. (338° F.), dipping into the water. The properties of the rubber thus treated ought not to be perceptibly altered.

4. *Ash.*—Calcine ½ to 1 gramme with care, with a very low flame at first.

It will be noticed that Lobry de Bruyn does not impose any maximum of sulphur. He in fact found rubbers with 7 and 7·3 per cent. of sulphur as satisfactory as those which contained 3 to 4 per cent. On the other hand, the limit fixed for the loss on extraction by alcoholic potash, 8 per cent., prevents the addition of too large an excess of sulphur. He limits himself to requiring that the rubbers stand the above tests well. He allows the addition of mineral substances, in greater or less proportion, according to the purposes for which they are intended to be used. He has had through his hands excellent sorts containing 25 per cent. and above that of mineral substances. Amongst these it seems to him that, weight for weight, zinc oxide alters the properties of rubber to the least extent. In regard to red rubbers, it might be stipulated that they be coloured exclusively with antimony sulphide and not with ochres, venetian red, and analogous pigments; it is a well-known fact that the former last much longer than the latter.

The Tables giving the results of Heinzerling and Pahl's experiments now follow :—

TABLE LXVI.—RESULTS OBTAINED BY HEINZERLING AND PAHL

CHEMICAL

A. SAMPLES PREPARED FROM THE AUTHORS' DATA.						Remarks.	Action of Sulphuric Acid.
Consecutive Number of Sample.	Para Rubber.	Sulphur.	Qualities and Nature of the Substances added.		Density before Testing.		Alteration in Weight.
	Per Cent.	Per Cent.					Per Cent.
I.	90	10	0	...	0·999	The samples in this series were vulcanised for one hour at 135° to 138° C. (275° to 280·4° F.), under a pressure of 3 to 3½ atmospheres.	÷ 4·259
II.	85	5	10	Antimony sulphide.	1·070		÷ 3·099
III.	75	5	20	Antimony sulphide.	1·101		÷ 3·521
IV.	80	10	10	Zinc oxide.	1·087		÷ 3·274
V.	50	10	40	Zinc oxide.	1·283		÷ 2·074
VI.	10	10	80	Zinc oxide.	1·514		÷ 1·810
VII.	80	10	5 5	Zinc oxide. Chalk.	1·184		÷ 2·930
VIII.	50	10	20 20	Zinc oxide. Chalk.	1·255		÷ 2·280
IX.	10	10	40 40	Zinc oxide. Chalk.	1·452		÷ 1·802
X.	50	10	20 20	Zinc oxide. Calcium fluoride.	1·295		÷ 1·464
XI.	10	10	40 40	Zinc oxide. Calcium fluoride.	1·502		÷ 1·527
XII.	50	10	20 20	Zinc oxide. Lead oxide.	1·340		÷ 1·864
XIII.	10	10	40 40	Zinc oxide. Lead oxide.	1·569		÷ 1·406
XIV.	Could	not be	perform	ed.	...		...
XV.	50	10	40	Vulcanised oil.	1·053		÷ 4·081
XVI.	30	10	60	Vulcanised oil.	1·052		÷ 2·473
XVII.	50	10	40	Oil treated with chloride of sulphur.	1·054		÷ 6·076
XVIII.	30	10	60	Oil treated with chloride of sulphur.	1·031		÷ 6·306
XIX.	87	10	3	Calcined magnesia.	1·130		÷ 0·932
XX.	87	10	3	Slaked lime.	1·027		÷ 0·924
XXI.	75	10	15	Paraffin.	1·075		÷ 4·806
XXII.	65	10	25	Paraffin.	1·041		÷ 3·273
XXIII.	Could	not be	perform	ed.	...		...
XXIV.	Could	not be	perform	ed.	...		...
XXV.	75	10	15	Terebenthine.	1·030		÷ 3·367
XXVI.	65	10	25	Terebenthine.	1·065		÷ 3·582
XXVII.	85	10	5	Glycerine.	1·062		÷ 5·921
XXVIII.	80	10	10	Glycerine.	1·060		÷ 6·571
XXIX.	80	10	10	Bitumen.	1·080		÷ 3·686
XXX.	70	10	20	Bitumen.	1·085		÷ 2·421
XXXI.	60	10	30	Reclaimed rubber (powder).	0·101		÷ 2·336
XXXII.	30	10	60	Reclaimed rubber (powder).	1·101		÷ 3·889
IA.	English sheet vulcanised in the cold.	5	...	...	0·925		÷ 1·344

Explanation of the Signs: + Augmentation ;

IN THEIR EXPERIMENTS ON VULCANISED RUBBER AND EBONITE.

EXPERIMENTS.

Action of Acetic Acid.		Action of Caustic Soda Lye.		Action of Ammonia.		Action of Colza Oil.	Action of Mineral Lubricating Oil.	Action of a Mixture of Mineral Oil 90 per cent., and Tallow 10 per cent.	Action of Illuminating Gas.
Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Volume.	Alteration in Volume.	Alteration in Weight.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
+ 2·912	+ 0·932	–	÷ 4·354	–	÷ 0·727	+ 23·214	+ 42·718	entirely dissolved.	+ 9·765
+ 2·985	+ 2·097	–	÷ 4·354	–	÷ 0·974	+ 20·617	+ 39·694	+ 53·846	+ 9·156
+ 3·846	+ 3·048	–	÷ 4·271	–	÷ 0·896	+ 28·431	+ 51·485	+ 34·615	+ 7·561
+ 4·854	+ 29·132	–	÷ 2·971	–	÷ 0·326	+ 25·242	+ 39·423	+ 21·782	+ 11·079
+ 28·155	+ 153·035	–	÷ ·0·084	–	÷ 0·314	+ 32·110	+ 43·519	+ 58·878	+ 10·085
+ 27·868	+ 116·950	–	÷ 0·087	–	÷ 0·779	+ 47·272	+ 36·440	+ 78·947	+ 7·674
+ 5·357	+ 30·887	–	÷ 2·824	–	÷ 0·629	+ 24·137	+ 40·178	+ 65·765	+ 10·863
+ 28·828	+ 131·899	–	÷ 2·059	–	+ 0·856	+ 37·247	+ 46·296	+ 77·570	+ 7·370
+ 29·464	+ 160·097	÷ 0·892	÷ 1·422	–	÷ 0·507	+ 27·193	+ 35·593	+ 65·853	+ 5·821
+ 17·475	+ 62·616	÷ 1·000	÷ 3·348	–	÷ 0·455	+ 28·853	+ 40·384	+ 51·923	+ 8·549
+ 31·730	+ 124·539	–	÷ 2·160	–	÷ 0·512	+ 28·571	+ 41·121	+ 65·048	+ 1·452
+ 12·765	+ 78·542	–	÷ 1·150	–	÷ 0·011	+ 37·894	+ 38·613	+ 53·763	+ 10·043
+ 23·711	+ 77·411	–	÷ 0·282	–	÷ 0·388	+ 28·712	+ 30·000	+ 47·916	+ 8·695
...	...	–	...	...	...	...	...	...	...
–	+ 0·560	÷ 1·388	÷ 5·745	–	÷ 0·787	+ 21·428	+ 50·714	entirely dissolved.	+ 11·793
–	+ 2·180	–	÷ 4·965	÷ 3·571	÷ 0·744	+ 20·339	+ 32·773	,,	+ 14·047
+ 1·709	+ 6·373	÷ 7·017	÷ 9·723	÷ 1·724	÷ 2·147	+ 11·111	+ 44·545	,,	+ 7·574
+ 2·970	+ 8·695	÷ 9·708	÷ 9·658	÷ 1·941	÷ 1·649	+ 14·423	+ 55·445	,,	+ 7·987
+ 4·231	+ 18·718	–	÷ 1·321	–	÷ 0·247	+ 6·250	+ 36·440	,,	+ 10·143
+ 4·273	+ 6·297	÷ 0·847	÷ 6·569	–	÷ 0·327	+ 18·487	+ 29·752	,,	+ 10·043
+ 5·063	÷ 0·354	÷ 10·588	÷ 5·602	–	÷ 1·722	+ 23·595	+ 43·750	,,	+ 12·758
+ 2·197	÷ 0·674	÷ 7·692	÷ 4·847	–	÷ 2·882	+ 10·000	+ 35·781	,,	+ 13·581
...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...
–	+ 2·732	–	÷ 5·210	–	+ 0·239	+ 20·491	+ 39·603	entirely dissolved.	+ 10·363
–	+ 6·442	–	÷ 5·961	–	+ 0·496	+ 26·732	+ 31·460	...	+ 11·382
–	÷ 0·420	÷ 5·940	÷ 7·628	–	+ 0·308	+ 23·904	+ 48·214	...	+ 11·618
–	+ 2·400	÷ 3·846	÷ 7·992	–	+ 3·909	+ 21·551	+ 45·794	...	+ 8·905
+ 1·980	+ 0·650	–	÷ 4·382	–	+ 0·121	+ 10·434	+ 45·714	+ 73·684	+ 12·514
–	÷ 0·607	–	÷ 3·425	–	+ 0·225	+ 17·647	+ 40·740	+ 75·757	+ 11·248
–	+ 0·332	÷ 2·849	–	–	+ 0·718	+ 14·150	+ 53·846	entirely dissolved.	+ 10·810
–									
+ 1·769	+ 0·729	÷ 0·833	÷ 3·473	+ 0·869	÷ 2·031	+ 15·789	+ 47·000	,,	+ 5·807
–	–	–	–	–	+ 1·592	+ 28·461	+ 51·198	,,	+ 15·121

÷ diminution ; – no change.

TABLE LXVIa.—RESULTS OBTAINED BY HEINZERLING AND PAHL

CHEMICAL

B. Commercial Goods the Composition of which was given by the Factory.							Modules of Resistance in Grammes for 1 Square Millimetre.	Modulus of Load in Grammes for 1 Square Millimetre.
Consecutive Number of Sample.	Rubber.	Sulphur.	Quantities and Nature of the Substances added.		Density given by the Factory after Manufacture.	Density found 2½ Years afterwards.		
	Pr. Ct.	Pr. Ct.	Pr. Ct.					
1	91	9	0	...	0·990	0·999	33·5	201
2	82	8	10	Chalk.	1·100	1·111	40	230
3	43	5	7 45	Vulcanised oil. Oxide of zinc.	1·400	1·490	21	349
4	47	7	27 19	Chalk. Zinc oxide.	1·400	1·500	38·5	124
5	66	0	16 9 9	Antimony sulphide. Chalk. Zinc oxide.	1·200	1·304	43	173
6	70	7	23	Chalk.	1·465	1·222	15	86
7	92	0	8	Metal (1).	0·999	1·111	16	25
8	71	7	16 6	Chalk. Zinc oxide.	1·450	1·660	31·5	63
9	58	0	6 30 5 1	Vulcanised oil. Chalk. Metal (1). Pasta (2).	1·215	1·330	12	33
10	36	6	4 27 27	Vulcanised oil. Chalk. Oxide of zinc.	1·550	1·720	37·5	183
11	31	6	6 15 40 2	Vulcanised oil. Chalk. Oxide of zinc. Pasta (2).	1·600	1·806	36	145
12	39	0	4 10 3 3 ½ 32 8	Vulcanised oil. Chalk. Zinc oxide. Metal (1). Paraffin. Fluor spar. Mixture (3).	1·650	1·920	24	81
13	21	0	8 6 52 ½ ½ 11	Antimony sulphide. Vulcanised oil. Chalk. Paraffin. Pasta. Regenerated.	not given by the factory.	1·760	41·5	116
14	30	0	40 25 3 2	Chalk. Zinc oxide. Metal (1). Pasta (2).	*id.*	1·803	38·5	161
15	30	0	18 3 2 35 12	Chalk. Metal (1). Pasta (2). Fluor spar. Lead oxide.	*id.*	2·041	22·5	61

Explanation of the Signs: + Augmentation ;

IN THEIR EXPERIMENTS ON VULCANISED RUBBER AND EBONITE.

EXPERIMENTS.

Action of Acetic Acid.		Action of Caustic Soda Lye.		Action of Ammonia.		Action of Colza Oil.	Action of Mineral Lubricating Oil.	Action of a Mixture of Mineral Oil 90 per cent., and Tallow 10 per cent.	Action of Coal Gas.
Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Volume.	Alteration in Volume.	Alteration in Weight.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
+ 0·714	+ 2·540	–	÷ 1·934	–	+ 1·503	+ 18·045	+ 36·641	+ 89·312	+ 12·431
+ 19·083	+ 37·688	–	÷ 2·332	+ 3·937	+ 3·357	+ 6·666	+ 23·664	+ 70·992	+ 12·139
+ 34·259	+ 51·319	–	÷ 3·058	+ 0·402	+ 4·309	+ 47·663	+ 31·428	+ 84·955	+ 6·027
+ 46·216	+ 81·790	–	÷ 1·847	+ 4·001	+ 4·722	+ 3·703	+ 10·077	+ 55·118	+ 5·596
+ 42·975	+ 90·209	–	÷ 0·564	+ 16·071	+ 2·877	+ 6·140	+ 12·931	+ 7·692	+ 8·271
+ 37·190	+ 72·947	–	÷ 1·534	+ 5·660	+ 6·600	+ 5·737	+ 12·068	+ 18·333	+ 8·059
+ 2·205	+ 26·263	÷ 1·470	÷ 1·266	+ 11·450	+ 23·550	–	+ 8·450	+ 34·677	+ 8·413
+ 9·278	+ 53·321	–	÷ 1·600	+ 15·217	+ 17·652	+ 6·382	+ 18·556	+ 54·347	+ 4·836
+ 7·627	+ 78·623	–	÷ 4·650	+ 10·250	+ 22·405	–	+ 5·042	+ 13·559	+ 4·133
+ 19·841	+ 11·298	–	÷ 19·083	+ 6·299	+ 6·863	+ 27·480	+ 30·708	+ 81·679	+ 4·494
+ 21·481	÷ 13·589	÷ 0·699	÷ 20·551	+ 4·347	+ 6·238	+ 20·595	+ 21·428	+ 64·492	+ 5·069
+ 15·126	+ 31·422	–	÷ 14·724	+ 7·438	+ 6·009	+ 27·168	+ 22·413	unmeasurable.	+ 5·843
+ 17·355	+ 21·078	–	÷ 1·601	+ 9·090	+ 8·391	+ 15·125	+ 14·876	+ 47·580	+ 4·020
+ 21·705	+ 15·703	–	÷ 1·655	+ 10·156	+ 8·665	+ 7·031	+ 8·064	+ 33·343	+ 3·837
+ 21·538	+ 15·228	–	÷ 0·163	+ 6·666	+ 6·474	+ 10·687	+ 11·627	÷ 27·480	+ 3·122

÷ diminution ; – no change.

TABLE LXVII.—RESULTS OBTAINED BY HEINZERLING AND PAHL

PHYSICAL

A. Samples prepared from the Authors' Data.						Remarks.	Modulus of Load in Grammes for 1 Square Millimetre.	Modulus of Resistance in Grammes for 1 Square Millimetre.
Consecutive Number of Sample.	Para Rubber.	Sulphur.	Quantities and Nature of the Substances added.		Density before Testing.			
	Pr. Ct.	Pr. Ct.	Pr. Ct.			The samples in this series were vulcanised for one hour at 135° to 138° C. (275° to 280·4° F.), under a pressure of 3 to 3½ atmospheres.		
I.	90	10	0	...	0·999		48·5	213
II.	85	5	10	Antimony sulphide.	1·070		38	213
III.	75	5	20	Antimony sulphide.	1·101		47·5	259
IV.	80	10	10	Zinc oxide.	1·087		48·5	427
V.	50	10	40	Zinc oxide.	1·283		47·5	480
VI.	10	10	80	Zinc oxide.	1·514		43·5	543
VII. . . .	80	10	5 5	Zinc oxide. Chalk.	1·184		46	440
VIII. . . .	50	10	20 20	Zinc oxide. Chalk.	1·255		65	542
IX.	10	10	40 40	Zinc oxide. Chalk.	1·452		69	653
X.	50	10	20 20	Zinc oxide. Calcium fluoride.	1·295		48	404
XI.	10	10	40 40	Zinc oxide. Calcium fluoride.	1·502		77·5	563
XII. . . .	50	10	20 20	Zinc oxide. Lead oxide.	1·340		31·5	404
XIII. . . .	10	10	40 40	Zinc oxide. Lead oxide.	1·569		31	352
XIV. . . .	Could	not be	execu	ted.	...		...	...
XV.	50	10	40	Vulcanised oil.	1·053		22·5	220
XVI. . . .	30	10	60	Vulcanised oil.	1·052		22·5	77
XVII. . . .	50	10	40	Oil treated with chloride of sulphur.	1·054		16	66
XVIII. . . .	30	10	60	Oil treated with chloride of sulphur.	1 031		15	55
XIX. . . .	87	10	3	Calcined magnesia.	1·130		70·5	427
XX.	87	10	3	Slaked lime.	1·027		45	225
XXI. . . .	75	10	15	Paraffin.	1·075		15	109
XXII. . . .	65	10	25	Paraffin.	1·041		14	115
XXIII. . . .	Could	not be	execu	ted.	...		...	...
XXIV. . . .	Could	not be	execu	ted.	...		...	...
XXV. . . .	75	10	15	Terebenthine.	1·030		15	96
XXVI. . . .	65	10	25	Terebenthine.	1·065		12	51
XXVII. . .	85	10	5	Glycerine.	1·062		29·5	376
XXVIII. . .	80	10	10	Glycerine.	1·060		25·5	365
XXIX. . . .	80	10	10	Bitumen.	1·080		45	342
XXX. . . .	70	10	20	Bitumen.	1·085		67·5	407
XXXI. . . .	90	10	30	Reclaimed rubber (powder).	1·101		29	178
XXXII. . .	30	10	60	Reclaimed rubber (powder).	1·101		25·5	156
IA.	English sheet vulcanised in the cold.	5	...	...	0·925		38·5	230

IN THEIR EXPERIMENTS ON VULCANISED RUBBER AND EBONITE.

Experiments.

Limit of Elasticity in Millimetres for 100 Millimetres.	Alteration of Shape under Strong Pressure.				Alteration of Shape under Repeated Blows of the Hammer.				Insulating Power.	Action of Heat.
	Initial Thickness in Millimetres.	Thickness of the Swollen Edges in Millimetres.	Thickness of the Middle in Millimetres.	Displacement of the Extreme Edges in Millimetres.	Initial Thickness in Millimetres.	Thickness of the Swollen Edges in Millimetres.	Thickness of the Middle in Millimetres.	Displacement of the Extreme Edges in Millimetres.	Constant Depressions.	
1100	0·95	1·18	0·93	9·00	0·95	1·54	0·74	2·75	117	Normal.
790	1·36	1·48	1·27	9·00	1·31	1·68	1·03	4·50	12	,,
850	1·08	1·16	1·01	8·25	1·10	1·40	0·90	5·00	6	,,
825	1·01	1·07	0·98	9·50	1·00	1·31	0·82	4·50	171	,,
725	1·12	1·15	1·10	9·50	1·09	1·40	0·91	4·75	123	,,
660	1·17	1·20	1·11	9·50	1·11	1·35	0·99	5·50	4	,,
760	1·05	1·15	1·01	9·00	1·05	1·30	0·91	4·25	4	,,
710	1·09	1·20	1·02	9·00	1·02	1·28	0·90	4·75	4	,,
665	1·14	1·21	1·03	9·00	1·13	1·56	0·95	5·00	3·5	,,
660	0·98	1·02	0·91	9·00	1·00	1·42	0·82	4·75	2	,,
640	1·03	1·07	0·95	9·00	1·09	1·26	0·89	4·50	3·5	,,
490	0·94	0·89	0·85	8·25	0·93	1·15	0·82	3·50	225·7 3′ 15″	,,
305	0·91	0·84	0·86	8·00	0·91	1·19	0·78	4·00	220·5 3′ 45″	,,
...	...	...	...	...	...	...	...	...	...	...
750	0·85	0·96	0·75	6·50	0·78	1·22	0·67	4·75	9	Fumes if temperature be raised.
360	1·19	unmeasurable.	0·92	4·25	1·15	1·21	0·91	5·00	2	,,
600	0·96	1·21	0·84	5·50	1·02	1·05	0·73	3·75	50	,,
455	1·00	1·29	0·91	unmeasurable.	0·94	0·96	0·64	4·50	222 3′ 30″	,,
465	1·04	1·08	1·03	10·00	1·01	1·26	0·91	4·50	7·5	Normal.
665	1·23	1·35	1·06	8·50	1·21	1·55	0·96	3·25	9·5	,,
830	0·91	1·13	0·78	7·50	1·21	1·55	0·96	3·25	1	At a higher temperature fumes.
1025	1·15	1·20	1·01	7·25	1·11	1·45	0·77	5·75	0	,,
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
825	1·06	1·25	0·97	8·50	1·16	1·54	1·01	3·25	1·5	At a higher temperature fumes become pitchy.
630	1·02	1·21	0·91	8·50	1·09	1·26	0·82	4·00	1·5	,,
975	1·07	1·41	1·00	7·75	1·03	1·64	0·89	4·25	3	At a higher temperature fumes.
1050	1·14	1·35	1·03	8·00	1·16	1·92	0·92	2·50	5	,,
950	1·25	1·92	1·15	4·50	1·28	1·73	1·06	3·75	2	Normal.
875	1·07	1·42	0·95	3·50	1·08	1·49	0·90	2·00	2	,,
650	1·04	1·35	0·91	2·50	1·03	1·32	0·91	2·75	3·5	,,
600	1·25	1·44	1·17	4·50	1·42	1·86	1·08	4·00	1·5	,,
772	1·38	1·88	1·25	10·00	1·38	1·56	1·29	7·75	2·22 3″	,,

TABLE LXVIIa.—RESULTS OBTAINED BY HEINZERLING AND PAHL

PHYSICAL

B. COMMERCIAL GOODS THE COMPOSITION OF WHICH WAS GIVEN BY THE FACTORY.

Consecutive Number of Sample.	Rubber.	Sulphur.	Quantities and Nature of the Substances added.		Density given by the Factory after Manufacture.	Density found 2¼ Years afterwards.	Modulus of load in Grammes for 1 Square Millimetre.	Modulus of Resistance in Grammes for 1 Square Millimetre.
	Pr. Ct.	Pr. Ct	Pr. Ct.					
1	91	9	0	...	0·990	0·999	33·5	201
2	82	8	10	Chalk.	1·100	1·111	40	230
3	43	5	7 45	Vulcanised oil. Zinc oxide.	1·400	1·490	21	349
4	47	7	27 19	Chalk. Zinc oxide.	1·400	1·500	38·5	124
5	66	0	16 9 9	Antimony sulphide. Chalk. Zinc oxide.	1·200	1·304	43	173
6	70	7	23	Chalk.	1·165	1·222	15	86
7	92	0	8	Metal (1).	0·999	1·111	16	25
8	71	7	16 6	Chalk. Zinc oxide.	1·450	1·660	31·5	63
9	58	0	6 30 5 1	Vulcanised oil. Chalk. Metal (1). Pasta (2).	1·215	1·330	12	33
10	36	6	4 27 27	Vulcanised oil. Chalk. Zinc oxide.	1·550	1·720	37·5	183
11	31	6	6 15 40 2	Vulcanised oil. Chalk. Zinc oxide. Pasta (2).	1·600	1·806	36	145
12	39	0	4 10 3 3 ½ 32 8	Vulcanised oil. Chalk. Zinc oxide. Metal (1). ... Paraffin. Fluor spar. Mixture (3).	1·650	1·920	24	81
13	21	0	8 6 52 ½ ½ 11	Antimony sulphide. Vulcanised oil. Chalk. Paraffin. Pasta. Regenerated.	not given by factory.	1·760	41·5	116
14	30	0	40 25 3 2	Chalk. Zinc oxide. Metal (1). Pasta (2).	*id.*	1·903	38·5	161
15	30	0	18 3 2 35 12	Chalk. Metal (1). Pasta (2). Fluor spar. Lead oxide.	*id.*	2·041	22·5	61

Explanation of the Signs: + Augmentation;

IN THEIR EXPERIMENTS ON VULCANISED RUBBER AND EBONITE.

EXPERIMENTS.

Limit of Elasticity in Millimetres for 100 Millimetres.	Alteration of Shape under Strong Pressure.				Alteration of Shape under Repeated Blows of the Hammer.				Insulating Power.	Action of Heat.
	Initial Thickness in Millimetres.	Thickness of the Swollen Edges in Millimetres.	Thickness of the Middle in Millimetres.	Displacement of the Extreme Edges in Millimetres.	Initial Thickness in Millimetres.	Thickness of the Swollen Edges in Millimetres.	Thickness of the Middle in Millimetres.	Displacement of the Extreme Edges in Millimetres.	Constant Depressions.	
675	1·36	1·62	1·29	9	1·42	2·04	1·18	2·75	200·5	Normal.
600	1·26	1·75	1·24	5·50	1·32	1·72	1·08	1·50	98	"
580	1·10	1·27	1·04	7·50	1·14	1·48	1·02	4·75	16·5	At a high temperature gives off fumes, and the gum becomes yellow.
160	1·18	1·25	1·04	5·25	1·28	1·42	1·07	4·50	36·5	Becomes brittle, changes colour.
235	1·10	1·20	1·03	6·50	1·09	1·16	1·01	5	120·5	Becomes soft and spongy at 150° C. (302° F.).
190	1·25	1·32	1·16	7·25	1·29	1·36	1·10	5·25	146	Becomes hard and brittle.
110	1·21	1·06	0·91	7·50 (12·50)	1·24	1·01	0·90	6·25	5	Becomes hard and still more brittle.
145	0·39	0·76	0·82	7·50 (13·25)	0·92	0·87	0·75	7	221·5 after 4′ 15″	Intumesces and becomes brittle.
110	1·12	0·82	0·87	9·25 (14)	1·15	0·86	0·82	9·24	15	Still more brittle than the preceding.
550	1·29	1·35	1·20	7·75	1·29	1·64	1·12	4	157	From 40° to 50° C. (104° to 122° F.) shrivels and becomes brittle.
310	1·34	1·41	1·27	6·50	1·38	1·46	1·24	5·25	250·5	Shrivels.
270	1·25	1·21	1·04	6·50 (12·50)	1·24	1·08	1·05	7	247	Becomes very soft.
140	1·16	0·91	1·18	6·25	1·23	1·07	1·03	9 (12)	134	Becomes spongy and brittle above 130° (266° F.).
125	1·27	0·78	1·07	8·25 (14·50)	1·24	1·06	1·03	9·25 (12·50)	101	Becomes brittle.
110	1·31	0·88	0·90	8 (15·50)	1·32	1·22	1·04	8·25 (12)	226	Becomes spongy and brittle.

÷ diminution ; – no change.

TABLE LXVIII.—RESULTS OBTAINED BY HEINZERLING AND PAHL

1. CHEMICAL

C. SAMPLES OF EBONITE PREPARED FROM THE AUTHORS' DATA.						Remarks.	Action of Sulphuric Acid.
Consecutive Number of Sample.	Rubber.	Sulphur.	Quantities and Nature of the Substances added.		Density.		Alteration in Weight.
	Per Cent.	Per Cent.	Per Cent.				Per Cent.
XXXIII.	80	20	0	...	1·095		÷ 2·028
XXXIV.	60	20	10 10	Terebenthine.[1] Rosin.	...		+ 15·133
XXXV.	50	20	15 15	Terebenthine. Rosin.	...		÷ 2·018
XXXVI.	60	20	20	Bitumen of Judea.	...		+ 28·531
XXXVII.	40	20	40	Bitumen of Judea.	...		÷ 9·504
XXXVIII.	70	20	10	Mercury sulphide.	1·177		÷ 3·225
XXXIX.	60	20	20	Mercury sulphide.	1·384		+ 17·551
XL.	40	20	10 30	Terebenthine. Calcic hydrate.	1·275		÷ 2·603
XLI.	10	20	10 60	Terebenthine. Calcic hydrate.	1·311		÷ 7·880
XLII.	40	20	10 30	Terebenthine. Calcined magnesia.	1·203		÷ 4·203
XLIII.	10	20	10 60	Terebenthine. Calcined magnesia.	1·428		÷ 8·333
XLIV.	65	35	...	...	...		–

Explanation of the Signs: + Augmentation ;

2. PHYSICAL

C. SAMPLES OF EBONITE PREPARED FROM THE AUTHOR'S DATA.						Remarks.	Modulus of Load in Grammes for 1 Square Millimetre.	Modulus of Resistance in Grammes for 1 Square Millimetre.
Consecutive Number of Sample.	Rubber.	Sulphur.	Quantities and Nature of the Substances added.		Density.			
	Pr. Ct.	Pr. Ct.	Pr. Ct.					
XXXIII.	80	20	0	...	1·095		43·5	105
XXXIV.	60	20	10 10	Terebenthine Rosin.	...		15	142
XXXV.	50	20	15 15	Terebenthine. Rosin.	...		12	46
XXXVI.	60	20	20	Bitumen of Judea.	...		17	69
XXXVII.	40	20	40	Bitumen of Judea.	...		24	244
XXXVIII.	70	20	10	Mercury sulphide.	1·177		32·5	197
XXXIX.	60	20	20	Mercury sulphide.	1·384		61	341
XL.	40	20	10 30	Terebenthine. Calcic hydrate.	1·275		22·5	122
XLI.	10	20	10 60	Terebenthine. Calcic hydrate.	1·311		10	55
XLII.	40	20	10 30	Terebenthine. Calcined magnesia.	1·203		31·7	390
XLIII.	10	20	10 60	Terebenthine. Calcined magnesia.	1·428		25·9	272
XLIV.	65	35	...	...	...		excellent.	excellent.

[1] Presumably turpentine oleo-resin.

IN THEIR EXPERIMENTS ON VULCANISED RUBBER AND EBONITE.

EXPERIMENTS.

Action of Acetic Acid.		Action of Caustic Soda Lye.		Action of Ammonia.		Action of Colza Oil.	Action of Mineral Lubricating Oils.	Action of a Mixture of Mineral Oil 90 per cent., and Tallow 10 per cent.	Action of Coal Gas.
Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Weight.	Alteration in Volume.	Alteration in Volume.	Alteration in Volume.	Alteration in Volume.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
–	+ 0·746	–	÷ 2·692	–	+ 0·490	+ 12·068	+ 7·874	+ 20·000	+ 11·629
–	÷ 3·501	–	÷ 1·426	–	+ 0·611	+ 2·728	–	+ 2·932	+ 11·339
+ 2·608	÷ 4·989	–	÷ 0·187	–	+ 0·428	+ 1·428	–	+ 6·293	+ 8·053
–	÷ 7·345	–	÷ 0·112	–	+ 0·344	+ 6·440	+ 1·418	+ 26·086	+ 11·804
–	÷ 9·127	–	÷ 3·192	–	+ 0·478	+ 4·918	+ 1·515	+ 16·883	+ 10·062
+ 2·000	÷ 0·114	–	÷ 3·182	–	+ 0·406	–	+ 11·956	+ 41·758	+ 8·571
–	–	–	÷ 2·361	–	+ 0·281	–	+ 7·777	+ 33·707	+ 0·581
+ 3·200	+ 25·454	–	÷ 1·404	–	÷ 0·689	+ 0·862	+ 0·862	+ 20·000	+ 9·311
+ 4·964	+ 61·148	÷ 2 054	÷ 14·145	÷ 1·351	÷ 8·198	–	–	+ 7·284	+ 7·296
–	÷ 1·296	–	÷ 1·278	–	+ 0·396	–	–	–	+ 7·472
–	÷ 2·886	–	÷ 0·539	–	+ 0·396	–	–	–	+ 4·510
–	–	–	÷ 0·646	–	–	–	–	–	+ 3·569

÷ diminution ; – no change.

EXPERIMENTS.

Limit of Elasticity in Millimetres for 100 Millimetres.	Alteration of Shape under Strong Pressure.				Alteration of Shape under Repeated Blows of the Hammer.				Insulating Power.	Action of Heat.
	Initial Thickness in Millimetres.	Thickness of the Swollen Edges in Millimetres.	Thickness of the Middle in Millimetres.	Displacement of the Extreme Edges in Millimetres.	Initial Thickness in Millimetres.	Thickness of the Swollen Edges in Millimetres.	Thickness of the Middle in Millimetres.	Displacement of the Extreme Edges in Millimetres.	Constant Depressions.	
145	1·25	1·44	1·17	4·50	1·26	1·23	1·20	...	103	Normal.
175	2·30	1·71	...	10·50	2·38	2·25	2·25	10·000	575	Disengages fumes.
135	1·04	0·89	0·89	11·50	2·07	1·57	1·57	...	8	,,
145	1·67	1·65	1·66	11	1·92	1·67	1·67	11·25	60	Becomes soft.
175	1·72	1·54	1·55	12·25	2·81	2·24	2·25	11	2	,,
185	0·96	0·86	0·87	10	0·93	0·87	0·87	11·25	111	Normal.
190	0·91	0·89	0·89	10	0·95	0·93	0 93	10	46	,,
275	1·20	1·42	1·02	7·50	1·22	1·41	0·98	6·50	105·5	Disengages H_2S.
285	1·56	1·67	1·21	3·50	1·36	broken	...	...	3	,,
105	1·32	0·79	0·89	12·50	0·97	0·76	0·85	11·50	220 after 3′ 45″	Normal.
101·25	0·61	0·50	0·50	11·25	0·62	0·55	0·57	11	218 after 3′ 15″	,,
unknown.	1·27	1·27	1·27	10	1·25	1·29	1·29	edges scaly.	68	,,

Dynamometrical—The testing of rubber.—The indiarubber articles commonly employed are subjected to complicated mechanical stresses, which vary with the use the articles are put to. Their behaviour in each case is highly variable, as are the stresses, and it will be necessary to consider simple cases in order to draw simple conclusions concerning their mechanical properties. In the first case we will consider the modifications of form, volume, etc., which occur when a certain volume of rubber is subjected to strains along a known direction, where the deflections can be measured with exactitude. The stress may be caused either by extension or compression, and these are the two most interesting and easy cases to examine. We will take first of all the case of rubber subjected to a tensile strain. In by far the majority of cases the articles supplied by factories to their customers are in their daily use subjected more or less to mechanical strains, and it is essential that users should satisfy themselves that the articles are adapted to support such strains. This cannot be done without a dynamometer,. which will subject their materials to an accurate test in conditions approximating as closely as possible to those to which they will be subject in use. These conditions are extremely variable. It must be an accurate and convenient apparatus, capable of supplying all possible data by means of the tests which it furnishes. Nothing is more difficult than to fulfil the conditions which are essential for the contrivance of an apparatus of this kind. One apparatus for the industries concerned consists of the new P. B. dynamometer, which enables woven fabrics, indiarubber, wire, cord, thin sheeting, etc., to be tested; it can be used for tensile tests, compression tests, bending tests, slow or repeated tests; it will serve for tests of abrasion, for determining the coefficient of friction, plasticity, etc. By its aid tests can be carried out at ordinary atmospheric temperature, or at temperatures above and below that of the surrounding air. Finally, diagrams, which are automatically traced out, may combine all the interesting coefficients of the above-mentioned tests.

The dynamometer illustrated is horizontal. It consists of a solid cast-iron table *p*, faced perfectly true in its upper part, which rests on two strong cast-iron legs stiffened by cross-stays; on the table are the two principal parts of the dynamometer: the apparatus producing the stresses and the appliance for measuring them.

(a) *Appliance for measuring the stresses.*—In its design, balance levers, which are very cumbersome without being more accurate than the special steel spring adopted, were put on one side. A well-gauged and thoroughly tempered spring, not working under a maximum load, which crushes it down completely, is a highly accurate and very convenient measuring appliance. The spring *a* is compressed against a small cross-piece *t*, by a rod passing along its axis and carrying one of the locking jaws *e*, for the test pieces. On this rod there is gripped, between two nuts, a cam *b*, which governs a rack *j*, the latter rotating a gear wheel *k* with vertical shaft. On the shaft of this gear wheel is fixed a needle *l*, which shifts along graduation marks *m*. When the test piece breaks, the spring expands, but leaves the needle *j* in its position; consequently the breaking load can always be precisely read off. Every measuring appliance *must be capable of being thoroughly checked* from time to time. To provide for this checking the measuring spring is fitted between two small columns *x' x'* which connect the two small cross-pieces. The end cross-piece carries an eye-bolt *h*, and the whole of the spring of the two cross-pieces may be unbolted and taken off the apparatus. By suspending the whole to a hook by the eye-bolt *h*, and hanging marked weights on the clamp *e*, the apparatus for measuring the dynamometer strains may therefore be tested at all times.

(b) *Strain producing apparatus.*—The piece to be tested (by tension, for instance) is locked between the two clamps *e* and *f*, as shown on Fig. 94. This latter jaw is connected with a slide *g*, which in turn is connected with another slide *o* by a screw *n*. This screw is actuated at two speeds; at the higher speed (when desired to operate quickly) by means of the horizontal hand-wheel carried on the support *o*; this wheel controls the screw by a bevel gearing; at the smaller speed

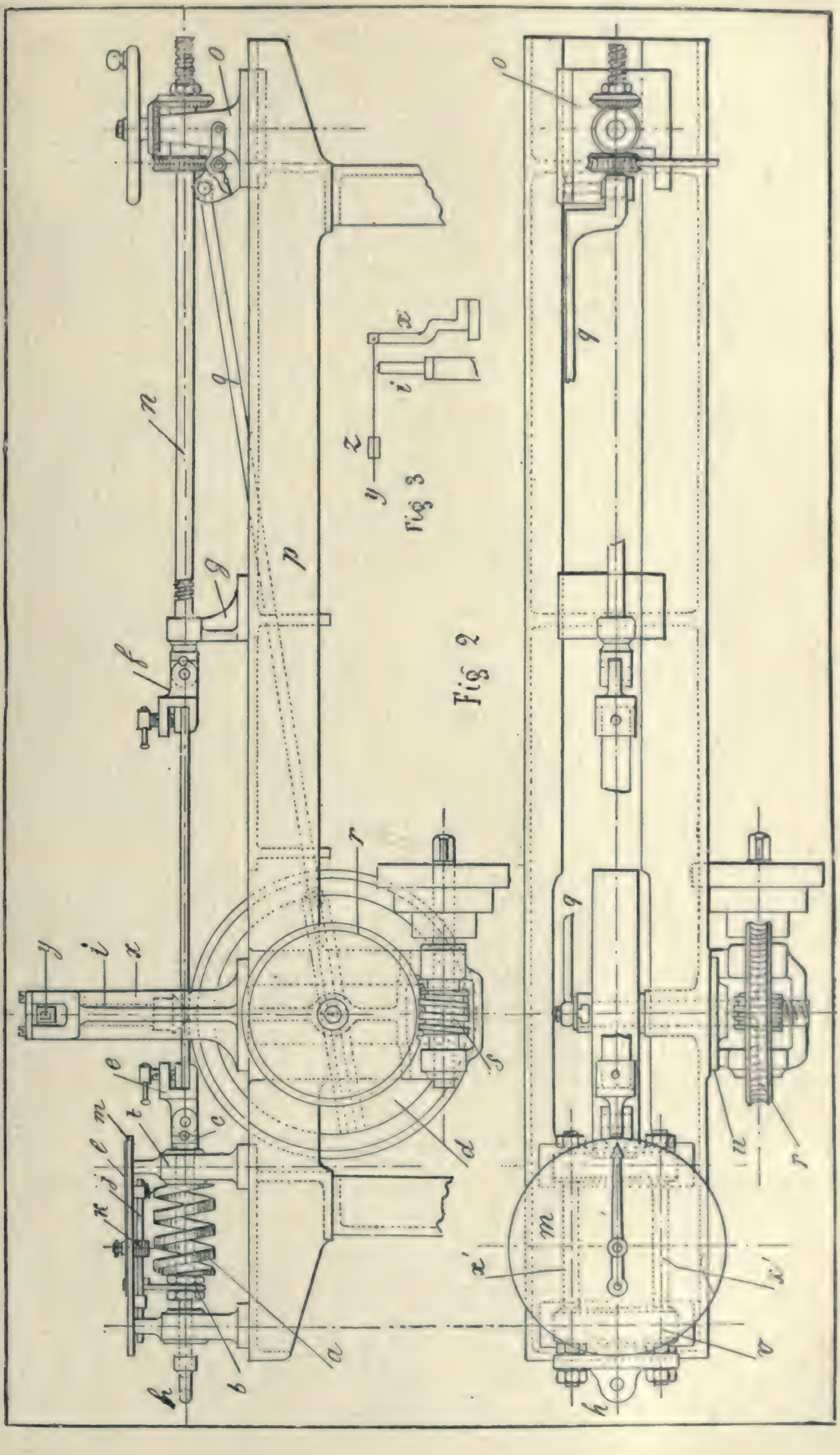


FIG. 94.—Dynamometer diagrams.

(when a great pull is to be developed) by means of a tangent screw actuating the gear wheel carried on the front of the support *o*.

(c) *Oscillating apparatus.*—The two parts *g* and *o* may be locked on the table or loosened as desired. To the lower part of *o* is attached a connecting rod *q*, controlled by an eccentric wheel. If therefore the two slides *g* and *o* are set free, and this eccentric wheel is put in motion, a series of repeated tensions may be exercised on the test piece. The width of travel may be varied by altering the position of the crank pin on the eccentric wheel. The eccentric wheel is carried at the end of a horizontal shaft, at the other end of which is keyed the gear wheel *r*, operated by a tangent screw *s* : on the spindle of this latter is fitted a three-step cone capable of giving varying speeds, and a small motor of some kind (preferably electric) can operate the whole by means of a small belt. A crank may be used for the same purpose. The eccentric wheel may be raised or lowered vertically; the purpose of this will be seen below.

(d) *Tensile tests at varying temperatures.*—To carry out tensile tests at the ordinary temperature the pieces are locked between the two clamps. These clamps have channels of increasing depth from their end to the bottom in order to avoid cutting the fabrics and indiarubber; moreover, other locking devices may be fitted when it is required to test hard bodies, such as ebonite and steel wire; channeled wedge locking-pieces are then used. For hemp cords small drums are employed. *All these are absolutely indispensable precautions for obtaining correct results.* When it is desired to test pieces of various materials by tension at a temperature differing from the atmospheric, these pieces are placed in a vat containing a liquid which may be heated or cooled. The clamps then have a bend to enable them to pass over the edge of the vat.

(e) *Compression tests at various temperatures.*—Compression tests are very well carried out by the dynamometer by fitting up between the clamps *e* and *f* a small so-called reversion appliance, which contains four plates coupled in pairs, and arranged in such a way that when the outside plates move apart the inside plates draw together. The pieces to be compressed are arranged between these two latter plates, and the test is carried out without any difficulty, with convenient measurements of the stresses and deformations. These tests may be made cold or at various temperatures under the same conditions as the tensile tests, and on bodies of every kind.

(f) *Plasticity tests.*—The plastic materials employed in industry are legion. Their chemical constitution is perfectly well known, but when their characteristic feature, plasticity, is in question, there are hardly any data available. The dynamometer P. B. system here once more fills a gap. It allows of measuring with precision the plasticity of soft bodies. For this purpose the latter are enclosed in a small cylinder shut at the bottom by means of a plug in which a hole is drilled. On the soft body (wax, plastic mixture, etc.) a piston is rested, which rises without friction in the cylinder, and it is noted what pressure is required to make the soft body flow out through the aperture in the plug, and what quantity of matter can flow out in a given time. To make the test the arrangement is fitted up in a small reversion appliance as for compression. The plasticity test may be made cold or hot. Special attention is asked to the importance of this most essential point.

(g) *Repeated bending tests.*—The work to which certain parts are subjected when in use is not only the result of slow stresses, but, above all, repeated stresses. That is why this dynamometer is provided with all that is required for carrying out tension, compression, and repeated flexion tests. The apparatus for bending tests is somewhat different from that for tension and compression. Take for instance a layer of woven fabric in a pneumatic tyre, and see how it behaves under use. In the first place the fabric is distended by the pressure of the air in the inner tube, and afterwards, in use of the tyre, this fabric will have to undergo repeated bending. It is essential to approximate to these combined modes of strain and stress when required to test pneumatic tyre webbing.

The dynamometer in question admits of doing this with facility, and is

applicable to many similar cases. For this purpose the fabric (or any piece of indiarubber, cord, thin sheeting, etc.) is first drawn out to a known tension by means of the ordinary tension jaws *e* and *f* of the dynamometer. On the frame of the dynamometer a small column is placed carrying a slide provided with two rollers, between which the strip of fabric to be bent passes. This slide is moved on both sides alternately of the run of the strip of fabric (or on one side only if desired) by means of a small connecting rod operated by the eccentric wheel already referred to. It will be clearly seen that the strip may thus be indented by known quantities, and the number of bendings noted before it is disrupted. The information which may be gained in this way is of the utmost importance. It will be observed that the clamps *e* and *f* of the apparatus are fitted on horizontal shafts, which allow the strip to oscillate within perfectly defined and accurate limits. By this arrangement it can be ascertained what range of stresses in the distended strip correspond to a deformation in that strip. The speed and width of the deformations can be varied just as in the tensile or bending tests already referred to.

(h) *Abrasion tests and determining coefficients of friction.*—One of the most important features of this dynamometer relates to the possibility of determining by its aid both the wear and tear and the coefficient of friction of woven fabrics, indiarubber, wood, metal, etc. The following is the procedure adopted to this end :—

On the table of the dynamometer a small column is placed carrying a graduated double-arm lever arrangement, along which an index moves, to which a marked weight may be suspended. This lever is supported on a vertical rod accurately guided in the column, and on its lower part this rod carries a pillow which presses on the piece to be abraded. This test piece may be of any kind ; when it is a long, soft body, it is held between the two clamps *e* and *f*, drawn out to a suitable tension, and the pillow on the above rod pressed upon it. On the other hand, the rim of the eccentric wheel is provided with a removable abrasion crown, and contact made between the bottom of the strip to be abraded and the abrading crown. The process of operation will be immediately understood : the eccentric wheel wears down the test piece, whether it is a fabric, a rubber strip, an ebonite rod, or a metal strip, under conditions of speed and friction surface which may be varied as required. But the lever applying the pillow indicates the pressure under which the abrasion takes place ; this pressure is evidently a highly important factor in the wear, and this wear is ascertained by the loss of weight of the substance tested after a certain number of wheel revolutions. The coefficient of friction of the substance tested is easy to determine, because, under the action of the abrading crown, the strip tends to pull on the dynamometer spring ; the variation of tension caused by this action will be read off immediately on the appliance, and, on being referred to the initial tension to which the strip is subjected, will give the coefficient of friction of the latter. (1) *Perforating tests in fabrics or soft substances.*—A strip of fabric or indiarubber drawn tight, as in the abrasion test, can be perforated or cut without difficulty if, at the end of the pressure rod, a needle point or knife be fitted ; and the value of this arrangement lies in the fact that, on the one hand, tests of this kind can be carried out on a strip the degree of tautness of which is known, and with a precise measurement of the perforating pressure ; and that, on the other hand, the perforation or the cutting can be carried out on the free strip without support, or on the strip supported on the eccentric wheel. An approximation is thus made to what would take place in many cases in practice. The dynamometer is thus adapted for tests of an exceedingly wide range, and is thus so far superior to the ordinary dynamometers used in industry. Its value is still further enhanced by the fact that it can supply a faithful record of the tests carried out. This is effected by a diagrammatic record of the slow tensile and compression tests, owing to an improved record apparatus fitted on the table of the appliance. This recorder consists of a drum which can revolve as a function of the deformations of the pieces tested, by means of a wire which accurately follows the deformation at two points in these pieces. A special arrangement of tongs is

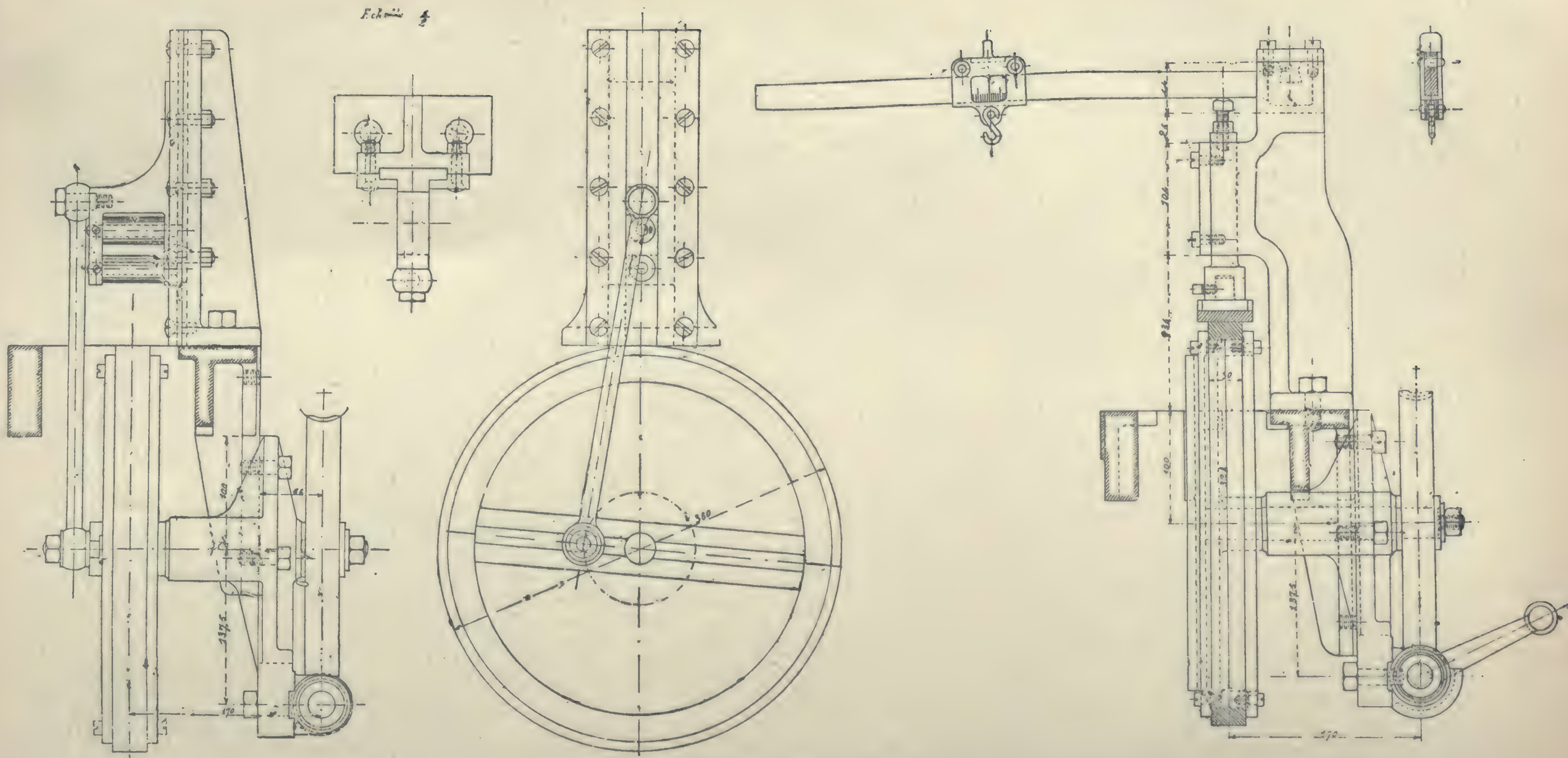


Fig. 95.—Dynamometer diagrams.

provided for this purpose. On the recording drum a tracing pen runs, following, and enlarging the deformations of the measurement spring of the apparatus.

Fig. 95 shows the dynamometer, as fitted up for carrying out the principal tests for which it is designed.

Fig. 96 represents the dynamometer installed for a tensile test on indiarubber or a fabric. The test piece subjected to tension can be submitted to alternating tensile force by means of the connecting rod, which can be driven at different

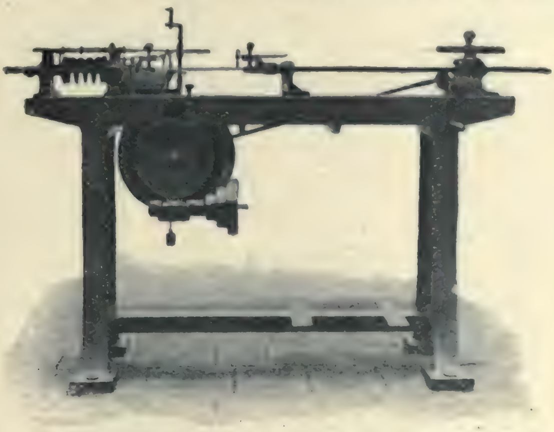


FIG. 96.—Dynamometer for the tensile testing of indiarubber.

speeds by the wheel operated by the tangent screw and the large pinion. The figure also shows the recording appliance.

The small wire bridging connects points on the two jaws, which follow the stretch of the strip, between two standard points, passes along the small support, which is plumb with the drum, and goes on from this point to operate the latter.

Fig. 97 shows the dynamometer as installed for compression tests. These tests

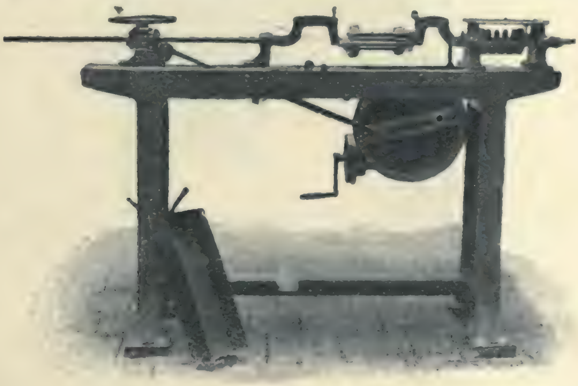


FIG. 97.—Dynamometer for compression tests.

are carried out by means of a four-plate appliance, which reverses the direction of tension of the dynamometer, and enables a test piece to be crushed between its middle plates. The bent form of the parts attaching this reversing appliance to the dynamometer clamps has been adopted to enable hot compression tests to be carried out. The small trough or tray used for these tests, with its gas connections, is supported against one of the legs of the appliance. The connecting rod and eccentric wheel allow these compression tests to be carried out on a continuous

system. On the dynamometer bench there will be observed a small piston and the cylinder used for tests on plastic bodies. The compression diagrams can be made in the same way as tension diagrams. The recorder has been taken off for the purpose of photographing.

Fig. 98 shows the dynamometer equipped for carrying out tests on fabrics or other substances by means of repeated bending. For this purpose the large con-

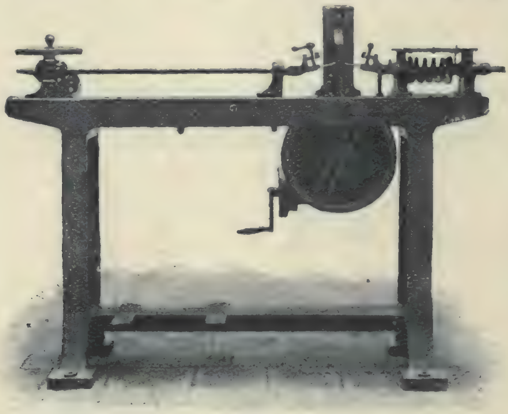


FIG. 98.—Dynamometer for repeated bending tests.

necting rod is taken down and a small one fitted in its place, and, on the other hand, on the bench of the apparatus there is fitted a support with slide carrying two rollers, between which the specimen to be bent passes. This specimen is previously drawn tight between the two locking jaws, and the bends give it an additional tension until it breaks. The bends may vary in width as required up

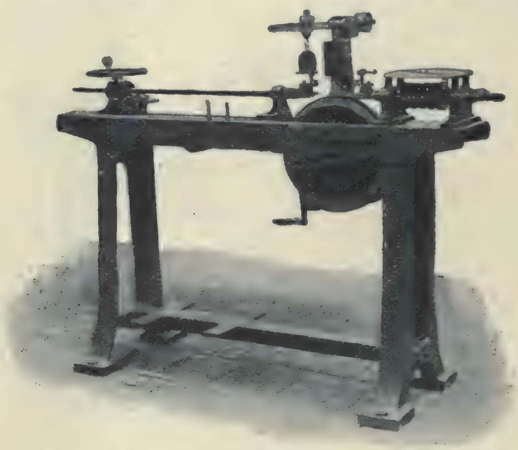


FIG. 99.—Dynamometer for abrasion tests.

to 50 millimetres, the slide of the large wheel being graduated and allowing of accurate measurement of this width. The clamps are jointed on their shafts and follow the bends of the fabric.

Abrasion tests.—Fig. 99 represents the dynamometer arranged for abrasion tests on various specimens. The specimen mounted in and seen on the figure is a strip of fabric. This strip is first drawn to a given tension between the clamps, and the eccentric wheel is then placed so that the upper part of this rim forms a tangent to

the tension shaft; it then comes into contact with the specimen piece to be abraded. On this latter is brought to bear a surfaced pillow, which is pressed against the fabric by means of a vertical rod guided in a bearing, the pressure being known and regulated by means of a balance lever loaded with a weight, which can be varied as desired. The eccentric wheel is put in motion, and with it the fabric, the latter exercising an *additional* tension on the measuring spring. This *additional* tension, divided by the weight pressing on the fabric, immediately gives the coefficient of friction between the fabric and the rim of the wheel. This rim may be covered with emery cloth or any other abrading substance. As it consists of a dismountable rim held laterally by two hoops, it may be replaced as desired by the operators, and the appliance attached to the screw, so that the lever is always horizontal, which is shown by a small index; in this way the fabric will be perforated, and the load causing the perforation noted.

Fig. 100 represents the dynamometer installed for abrasion tests, and in front of it are exhibited all its numerous accessories. The tracer pencil holder is driven by a cam cast on the tensile clamp attached to the measuring spring, and records the compressions of the spring along the generating lines of the drum, and con-

FIG. 100.—Dynamometer with all its accessories for abrasion tests.

sequently the stresses exercised. The diagram is thus traced automatically, which is of capital importance in a mechanism of the kind with which we are dealing, hand-traced diagrams being generally defective. The spring which serves for the measurement of the stresses of the appliances can easily be removed, and may be of varying power. In the dynamometer represented on the preceding figures there are available three springs, measuring 50, 200, and 1000 kilos. respectively. The sensitiveness of the appliance is therefore variable as required and according to the nature of the test, which is of great advantage. Of course there is a graduation of each spring on the dial of the apparatus, and the same needle allows of reading off on the three scales, by aid of an alidade fitted with crossed threads in which this needle terminates. The person in the illustration standing beside the apparatus shows the comparative size of the latter and its parts.

Patent rubber tester (*System Schopper-Dalén.*)—For mechanical tests, *i.e.* for ascertaining the strength and elasticity of rubber, a new apparatus suitable for testing rubber on the basis of the lever construction of strength testers, has been devised. The difficulty encountered in mechanical tests was, at the suggestion of Professor Dalén of the Royal Testing Institute at Gross-Lichterfelde, overcome

by employing for the tests ring-shaped test bodies instead of strips. This idea in conjunction with that of Schopper to move the ring-body positively proved to be an excellent one, and the apparatus now in question meets, in the most perfect manner, all demands to be made from the point of view of material-testing technics. It admits the exact establishment of the strength and elastic qualities of rubber in figure values, the exact determination of which had, hitherto, been found to be a matter of impossibility. The ring-shaped standard test bodies are cut out of

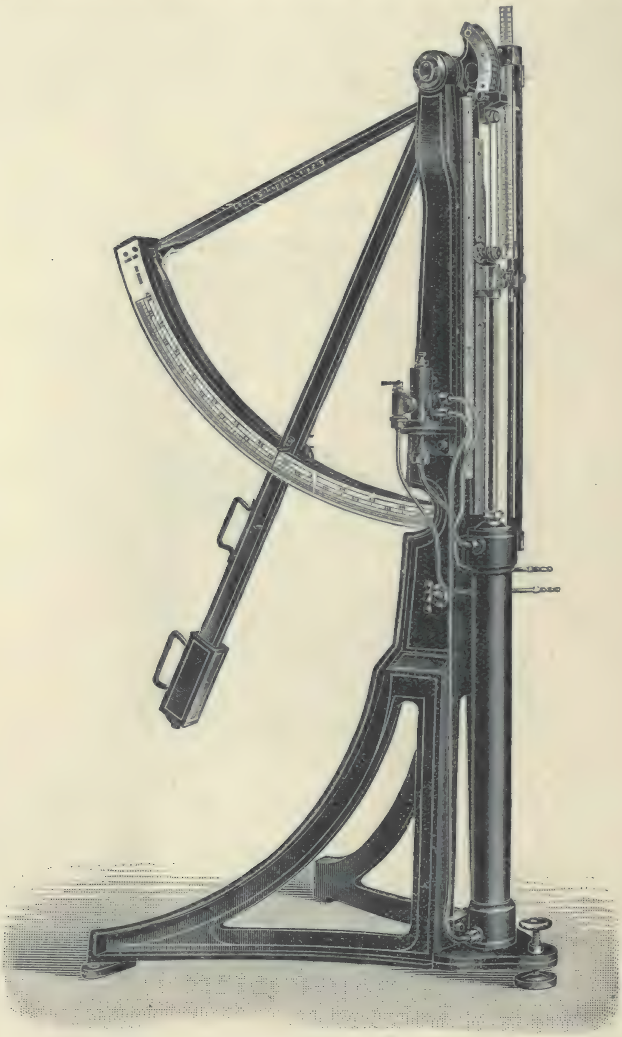


Fig. 101.—Machine for indiarubber tests (L. Schopper, Leipzig).

vulcanised plates on a cutting press. If it is necessary to test the quality of trial mixtures in the laboratory mechanically, trial plates are first vulcanised by means of devices accompanying the apparatus; then the standard bodies required for the test are cut out of them, or the material to be tested is vulcanised in annular moulds.

The apparatus is worked by water power, is fitted with the return valve, System Martens, and can be joined to any water pipe of about three atmospheres

pressure. At the moment of rupture, the weight-lever and the stretch-pointer are cut out automatically. An accurate record of strength and stretch, therefore, is given. In order to bring the apparatus to a standstill at any time in the course of the test, the steering valve is equipped with an instantaneous regulator-cock.

FIG. 102.—Cutting press for making standard test samples with two circular knives.

CHAPTER XII

RUBBER SUBSTITUTES—IMITATION RUBBER—ANALYSIS OF INDIARUBBER

THE high price to which rubber often rises, from one cause or another, has stimulated manufacturers to try to find whether it were not possible to replace this substance, wholly or partially, by cheaper natural or artificial products with analogous properties.

Elaterite—Coorongite.—Nature yields few substances capable of being used directly as substitutes for the solid hydrocarbides called rubber. That is why we simply mention the *fossil rubber* of Faujas de Saint Fond, found in the natural fissures of the Castleton mines,—a blackish, bituminous, compressible, even elastic substance resembling pieces of old leather, which was afterwards, under the name of *Elaterite*, shown to occur in the quarries in the neighbourhood of Angers in France, and of Newhaven, Connecticut, U.S.A. But this substance, only met with accidentally, and in infinitely small quantities, in the two localities above mentioned, is found at Coorony, Adelaide, and in South Australia, and is an article of commerce there. It has not been sufficiently examined to decide definitely as to its vegetable origin. It is found in rather thick deposits, in the sand of certain localities. Some authors assert that this product is simply the dried juice of a defunct vegetation, transformed by heat and the pressure of the deposits in which it is enclosed into resino-bituminous masses. Others attribute it to a mineral origin identical with that which produces naphtha and petroleum. *Elaterite* is a hydrocarbide of specific gravity of 0·982 to 0·990; it rather resembles certain varieties of rubber; it is soft, elastic, and ductile, burns with a fuliginous flame, but with no smell; it is adherent, but does not soil the hands; its natural smell is that of rubber, and it is easily cut. A finely cut lamina examined by the microscope exhibits a cellular, granular structure, traversed by a fibrous matter, just like a dried mushroom. This fact confirms the vegetable origin of coorongite, but it is difficult to conclude that it is simply the result of the heating and compression of vegetable tissue altogether altered in its nature, or that it is the dried juice of some plant. On dry distillation it yields 82 per cent. of gaseous and liquid hydrocarbides (Heinzerling). The special technical literature gives no indication of the direct use of this substance, but there is every reason to believe that it is used as an ingredient of certain inferior quality rubbers. There are no facts to prove the utility of such a mixture.

The list of natural rubber substitutes is therefore not a long one. It is not so with imitation rubbers, preparations due to the ingenuity of inventors or manufacturers: these products are more or less similar to rubber in some of their properties. Imitation rubbers generally have drying oils as basis, *e.g.* linseed oil, walnut oil, etc. (this latter oil is too dear, and is only mentioned to show that the same results can be got with it as with linseed oil). Receipts are innumerable; each maker has his own sleight-of-hand; practice and experience play an important part, and an irreproachable imitation is not made on the first attempt. Numerous experiments are necessary to arrive at right proportions and proper temperature. It is not intended to enumerate all known and proposed receipts for making imitation rubber. Published receipts are generally obsolete, fit to guide beginners in

practical researches, but not sufficient for immediate and profitable use in trade. It will suffice, therefore, to describe the preparation of the two principal varieties of imitation rubbers in most general use, namely—(1) oxidised oils; (2) vulcanised oils.

1. *Oxidised oils—Sace's experiments on action of nitric acid on linseed oil.*—Sace, whilst studying in 1846 the saponification of linseed oil by caustic soda, examined the action of nitric acid on that oil. When 100 parts of linseed oil and 200 parts of nitric acid, diluted with four times its volume of water, are gently heated with continual stirring, the oil assumes a brownish red colour; there is abundant disengagement of nitrous vapours, the oil thickens, and after four hours the mass acquires a very decided syrupy consistency. *Caoutchouc des huiles.*—L. Zonas, resuming in 1848 the experiments of Sace, set fire to linseed oil previously viscous, then, after having partially burnt it, he treated the residue with dilute nitric acid. This was the beginning of oxidised oil rubber substitutes (caoutchouc des huiles). *Sollier and Rattier's attempts.*—In 1854, F. Sollier, whether ignorant or not of these laboratory experiments, took in hand researches with the object of preparing from linseed oil a product capable of replacing rubber in some of its essential applications. Rattier patented a product of the same origin. *Present process.*—A certain proportion of linseed oil is heated until it is converted into a brown viscous mass. To thus convert 10 kilos. (say 22 lb.), it is necessary to heat for at least twenty-four consecutive hours. The viscous mass is afterwards treated in the hot state for a few hours with nitric acid until it has assumed a thick plastic consistency, and when cooled in the air becomes solid. The product is freed from excess of acid by kneading it for some time in a rather weak alkaline lye until it no longer has an acid reaction. When cold it exhibits the appearance of natural rubber; it is rather elastic, softens in hot water, and, unlike rubber, becomes plastic like gutta percha. It is soluble in spirits of turpentine, carbon disulphide, and alkalies. Acids precipitate it unchanged from its alkaline solution. The product was at once utilised for manufacture of waterproof canvas, imitation leather for saddlery and carriage building, and travelling articles of a suppleness and fitness leaving nothing to be desired. Its use, although less and less considerable for some time back, is still in vogue, and if it be but rarely used alone, it is still sometimes added to articles made from pure rubber. As it adheres perfectly to all fabrics without injuring them or penetrating them too deeply, the manufacturers of waterproof canvas often resort to it. It may also be applied without any difficulty to wood, to stone, and to metals, and in so doing it contracts a most remarkable adherence.[1]

2. *Vulcanised oils.*—Nickles and Rochleder first observed the action of sulphur chloride on fatty oils, by which they are transformed into a rubber-like substance. Mixed with any vegetable oil, sulphur chloride immediately converts that oil, almost at the ordinary temperature, into a solid, sometimes very hard substance.

Parkes' patent.—Parkes, to whom the process of vulcanising rubber by sulphur chloride is due, patented a process for vulcanising linseed and rape oils, also by sulphur chloride (British Patent, 22nd October 1855; No. 2359).

Roussin's researches.—In 1858, Roussin communicated to the Academy of Sciences the result of his researches on the action of sulphur chloride on oil (29th November). One hundred parts of linseed oil and about 25 parts of sulphur chloride

[1] Although nitric acid and linseed oil as described above yield a product somewhat analogous to the one next to be described, namely, that obtained by the action of sulphur chloride upon oils, yet in the latter case it would appear to be the sulphur which is the active agent, which explains why we can get a similar, if not the same, substance by using either drying or non-drying oils in the present case. However, in the solidification of linseed oil by oxidation by nitric acid, we are confronted with a rapid oxidation process exclusively confined to those oxidisable principles which are only found in drying oils. The oil is first heated so far as to render it viscous; it is then boiled for a long time with dilute nitric acid. A solid elastic brown substance, which does not stick to the fingers, is obtained, analogous to caoutchouc, whence its name of *black artificial rubber*. The same substance is obtained with the different drying oils, but in proportion to the intensity of their drying properties. Linseed and walnut oils yield eight to ten times as much as poppyseed oil.—Tr.

yield a compound possessing the maximum of hardness. One hundred parts of linseed oil and 15 to 20 parts of sulphur chloride yield a more supple product; whilst 100 parts of oil and 5 of chloride thicken the oil, but do not harden it. This latter compound is soluble in all ordinary oils, but thicker combinations only swell in these vehicles. When a certain quantity of linseed oil is diluted with thirty to forty times its weight of carbon disulphide, and if one-fourth of the weight of oil be replaced by the same quantity of sulphur chloride, a product is obtained which remains liquid for a few days. If this solution be applied on glass, wood, etc., the carbon disulphide evaporates immediately, and a coat of varnish is soon obtained. Several precautions must be taken in order to produce mixtures of chloride of sulphur and oil possessing the properties just referred to. A sulphur chloride containing the strongest possible proportion of sulphur must be selected. This liquid product is poured rapidly into the oil, and the mixture agitated in order to obtain a uniform mass. Soon the oil heats, the reaction is finished, and the oil hardens or forms a soft compound, according to the proportions of chloride. It is essential only to operate on small quantities at a time, and to avoid such an elevation of temperature as would volatilise the chloride, produce bubbles, and even blacken or carbonise the oil. Sulphur dichloride should never be used; its action is too strong and too rapid; the oil being treated would carbonise very rapidly, and the preparation would be irremediably burnt. When the two substances are intimately mixed, the product is run on to a glass plate, or upon another plane polished surface, where it is equalised, then, after the lapse of five to ten minutes, according to the temperature, combination is complete. As a final result a pellicle is obtained, which it is easy to raise; one of the corners is detached by the point of a knife, and the remainder gently pulled off by means of this corner. Moreover, several of these layers may be superimposed, taking care so that they may amalgamate together well, to apply one above the other when the latter is cold. In order to ensure perfect amalgamation, moisture must be avoided, which decomposes the chloride and prevents adherence. By working as just described, solid plates are obtained capable of being used in making numerous articles which could only be done previously with rubber. These articles are perfectly transparent, provided care has been taken after making them to keep them in an oven, or in a hot chamber, for a sufficiently long time for the vapours disengaged by the chloride to escape. They resist atmospheric influences, acids, and weak alkalies; but they are brittle, and emit a peculiar odour, from which it is difficult to free them. All vegetable oils may be used in the making of these substitutes, but linseed, rapeseed, earthnut and colza oils are preferred. Sometimes the action is moderated by the use of a solvent for both the oil and the sulphur chloride. One hundred lb. of the oil are mixed with 4 gallons of benzoline, and there is added a mixture of 25 lb. of sulphur chloride in 2 gallons of benzoline. The work should be done in a closed vessel provided with a stirrer, and the sulphur chloride should be added only in small quantities at a time. Some heat is generated, which causes the petroleum spirit to vaporise, whilst a little gentle heat at the end is sufficient to drive off the remainder. These sulphur chloride substitutes are generally of a pale yellowish colour, rather spongy in texture. They contain but little free oil and no free sulphur. They work with the rubber better than do the oxidised substitutes previously described.

Oils vulcanised by flowers of sulphur.—Rubber substitutes made from sulphur chloride, as we have just seen, are colourless, and in texture in no way resemble commercial rubber. Their manufacture is also delicate, and liable to very frequent failures, due principally to the too energetic action of the chloride upon the oil in presence of however slightly elevated a temperature. It has been found possible to overcome this difficulty by the direct vulcanisation of linseed oil by flowers of sulphur, which produces a black substance approaching more nearly to the natural colour of rubber, which, by its slower and more gradual elaboration, avoids the innumerable accidents of a reaction accomplished too rapidly. This substitute, which at the present day has in the greatest number of instances displaced oil

vulcanised by chloride of sulphur, is prepared as follows:—Linseed oil previously heated to a temperature of 100° C., is intimately mixed with 5 to 10 per cent. of flowers of sulphur, according to the object desired, then heated gradually to a temperature of about 130° C. (266° F.). The mixture rapidly turns brown, and when it has got to the desired temperature and acquired a very pronounced syrupy consistency, it is left to itself, without however allowing the temperature to lower below 100° C. (212° F.). Vulcanisation is known to be finished by the deep brown, almost black, colour of the mass, and its ever-increasing thickness. At this point the process is conducted in the same way as in the case of chloride of sulphur substitutes. That is to say, the vessels are emptied on smooth, cold surfaces so as to be able to detach the product after complete cooling. In making rubber substitutes from non-drying oils, the following formula has been given:—Take 100 lb. good Stettin colza oil, mix it intimately with 15 lb. of flowers of sulphur, and gradually heat the mixture with frequent stirring to a temperature of about 300° F., until a dark coloured, almost solid, mass is obtained. On cooling the substitute is of a rubber-like character, but devoid of the same elasticity and tenacity characteristic of rubber. During the process part of the sulphur enters into combination with the oil, part remains free. It is desirable that the free sulphur should be very small. The average amount is 2·5 per cent.; when the amount reaches 5 per cent. it becomes objectionable, as it tends to produce defective goods.

Rubber substitute from maize oil.—The manufacture of rubber substitutes is such a simple matter as to lie easily within the means of factories of ordinary capacity. It is assumed that the factory has the ordinary conveniences, and is piped for illuminating gas, for in the manufacture of "black sub" great heat is important, and is supplied by gas quickly and economically. A tank of boiler iron should be provided, cylindrical in shape, capable of holding one or more barrels of corn oil, and placed so it may be filled at its top. Such a tank, located in the factory basement, could be filled from barrels on the main floor with little trouble or waste by placing the tank immediately beneath the floor, which had been provided with a small hatchway or trap-door. The tank should be provided with faucet for drawing off oil as required, or it may be piped directly to the kettle for boiling. Gas jets should be arranged around the base of this tank, so that its contents can be heated in advance of use. This is simply economy in time. Within convenient distance of the tank should be another cluster or circle of gas jets in a chamber shut in at the sides, open at the top, properly constructed, and of a strength to sustain a kettle having a capacity of 8 gallons. Still another cluster of gas jets should be provided over which sulphur can be melted. Also a cooling box, 2 by 3 by 5 feet, constructed of wood. The apparatus now consists of a boiler iron tank for holding the supply of corn oil, a heater for boiling the oil, a heater for melting sulphur, and a cooling box. Two strong men are required to handle the work properly. Eight gallons of corn oil are drawn off from the tank, and 20¼ lb. of sulphur weighed into a large dipper, and each placed over its respective heater. The oil, having been previously heated, attains the boiling-point quickly, and for thirty minutes should be kept at a temperature of 470° F., and constantly stirred. The sulphur, being now melted, is added to the boiling corn oil. It must be added hot to prevent crystallisation. The workmen must be prepared for prompt and skilful action at this point, for no sooner does the sulphur mix with the boiling oil than the contents of the kettle rise rapidly, and before it can boil over must be removed and emptied into the cooling box, where it may be stirred. When cold it is dumped upon and tied up in large cloths, or placed in pans ready for use, as convenience or necessity suggest. In this manner black substitute is manufactured.

The boiling will reduce the quantity somewhat, say 2 per cent., and from a weight of 69¼ lb. material a batch should result weighing about 68 lb. It will be noted that something over 41 per cent. of sulphur is required to make this substitute, while to oxidise (vulcanise) cottonseed oil or rapeseed oil requires

but 26 per cent. A recipe which has been given for making sulphur chloride substitute from rapeseed oil is as follows :—

Rapeseed oil	½ gallon.
Benzine	1 ,,
Sulphur chloride	14 ounces.
Magnesia	½ ,,

The above-described rubber substitutes are sometimes employed alone in the manufacture of waterproof cloth, water pipes, etc. ; sometimes in combination with natural supple rubber for all other industrial uses.

But another substance likewise enters in considerable quantity into the class of rubber substitutes and imitations, namely, vulcanised rubber waste from the making of industrial objects or the rubbish of the trade, and which constitute the real rags of rubber articles. The Americans, who excel in the utilisation of this kind of substitutes, reclaimed rubber, consume enormous quantities of rubber waste, and produce from it really admirable articles. The processes for utilising this waste have already been given, and it would be simply repetition to return to them. The attention of manufacturers is called to this lucrative branch of the trade. The rubber substitute *Dermatine* was said to be discovered by Maxim Zingler, and recognised as such in England and Germany since 1885. This substitute is a simple mechanical mixture, agglomerated by heat and pressure, of supple rubber waste, textile fibres, leather shavings, and carbonate of magnesia, and identical with the vegetable ivory which Eugen Turpin presented to the Société d'Encouragement in July 1877, a report on which, by M. Cloez, appeared in the "Bulletin" of that Society (1877, p. 559). The product may interest certain manufacturers.

Notwithstanding the cheapness of substitutes, the favour in which they are esteemed in the majority of manufactories is a subject for regret, because they are far from adding anything to the value of the mixtures into which they enter. A method of analysing qualitatively and quantitatively a supple rubber loaded with substitutes, as well as the substitutes themselves, is therefore a necessity. Dr. Robert Henriques, already quoted, has published a series of researches on this subject, as novel as they are interesting, in the *Chemiker Zeitung* (1892, 1893, and 1894), reproduced by the *Moniteur Scientifique de Quesneville* (4th Series, VII., September 1893, and VIII., August 1894). This research throws a new light on the analysis of supple rubber, and also familiarises us with the study and intimate knowledge of substitutes :—

Contribution to the analysis of manufactured rubber and the detection of substitutes (R. Henriques).—The analysis of manufactured rubber is amongst the most complex analytical problems which the technical chemist may be called upon to solve. The determination of mineral substances used as make-weights, already difficult enough, becomes almost impossible when it is a question not only of ascertaining the proportions of the different oxides used, but also the form under which they were incorporated with the rubber. These difficulties are still further increased when it is desired to estimate the vulcanisation sulphur, because none of the published methods are reliable. Not the slightest indication is given in regard to the separation of the rubber from the make-weights of organic origin and substitutes; it would appear that no chemist has dared to enter this domain. Moreover, this is not a matter for surprise; the substances in question consist of an assemblage of bodies whose properties are badly known, which are about equally indifferent to all reagents, and which do not represent homogeneous chemical combination, but complex mixtures, like rubber itself, of dissimilar compounds. Having had to make numerous researches in this difficult path, Henriques was led to study a series of methods which appeared to remove, at least in part, the analytical difficulties referred to; and although this research may be far from throwing complete light on the obscure chemistry of rubber, it may be useful to those who may be occupied with similar questions, and contribute to augment and

improve the literature pertaining to this industry, which hitherto only presents but rare and meagre documents.

Difficulties in obtaining a fair average sample.—The taking of samples for analysis is at the outset the first difficulty. Manufactured rubber is not in reality a homogeneous substance, as its exterior aspect might suggest; moreover, the methods of manufacture of which it is the product readily explain its heterogeneity. Generally the heated and plastic rubber is mixed with sulphur and other substances; the moulded paste is treated with superheated steam. The masses of mineral bodies observed on cutting are the natural consequence of this incomplete method of mixture. Henriques analysed a large sheet of pliant rubber, containing amongst other substances a rather large percentage of silica. Whatever care was taken, the analysis yielded very divergent results: at one time, about 10 per cent. of SiO_2; at another time, 28 per cent.; whilst, at still another time, only 1·4 per cent. It was only after taking an average sample throughout the whole mass, by cutting strips along the axis and diagonals of the sheet, and afterwards dividing these strips into small fragments, and thoroughly mixing the whole, that concordant results were obtained. Henriques used the same method for ebonite, by filing with a rough file likewise in the direction of the axis and diagonals of the piece to be analysed. If, at the outset, such variations are observed in regard to the pulverulent fillers, how much more must they increase when the substances are coarse, such as fragments of glass, shavings, or cuttings of metal, which are frequently encountered? It is then, so to say, impossible, unless by previously disintegrating the whole piece, to obtain a satisfactory average sample.

The conclusions to be drawn are therefore:—

(1) In the analysis of rubbers it is always desirable to start with as copious samples as possible, and to prepare therefrom the average sample which is to be tested with as great care as possible.

(2) Care must be taken not to conclude, from the analysis of small samples of goods, that the analysis of the bulk is identical therewith.

1. *Ash.*—The determination of the ash is always recommended as the basis of all analyses of rubber. In my opinion, this determination teaches nothing in the majority of cases; at the most, it is only useful in the preliminary examination of containing only a small amount of mineral bodies.[1] But then there is nothing to show that ignition has not eliminated carbonic acid nor votatile metallic salts, reduced sulphates to sulphides, sulphuretted oxides, or, finally, burned free carbon. Several writers have already pointed out difficulties in the ash determination; but some try to cope with these by careful ignition, others, by addition of ammonium nitrate or carbonate—processes which might be of use in particular cases, but which are no more capable than the rough determination of general application. In any case, a separate heading has been given to the ash, the bearing of which is most often nil. For the quantitative analysis of the mineral substances, the previous estimation of the ash is of no use. Even for qualitative analysis, Henriques only used it with hesitation, because it is difficult to carry out in a porcelain crucible (clinkering of the substance), and the presence of certain bodies, litharge, for instance, does not allow of it being performed without risk in a platinum crucible. Henriques always determined the mineral matter simultaneously with the sulphur, as in No. 2.

2. *Sulphur determination.*—To determine total sulphur, it is generally recommended to unite the rubber with soda and saltpetre, with the addition of ammonium or magnesium nitrate. In whatever way Henriques applied the method, he was never able to obtain concordant results. If the nitrates be insufficient, the rubber burns, partially, with a luminous flame, and a non-neglectable portion of sulphur is dissipated with the ignition products. If the dose of ammonium nitrate be forced, the combustion is accompanied by a series of

[1] This does not apply to the analysis of raw rubber, and the rubbers called *pure Para*, which only contain, besides a small quantity of ash, sand, alumina, oxide of iron, and sometimes a small proportion of lime. The determination of the ash is then quite necessary.

small explosions, and it is difficult to avoid loss by projection. Even when the rubber is introduced into the fused oxidation mixture in very small fragments, it is difficult to avoid loss by deflagration. But Henriques obtained very good results by oxidising the rubber with nitric acid, and finishing the combustion by fusion with nitrate. Oxidation by nitric acid to the point where the addition of water no longer yields a precipitate is not enough, for with barium sulphate the insoluble salts of the organic acids separate, and the calcined sulphate shows an alkaline reaction. It is to destroy these organic acids that it is necessary to thoroughly finish the nitric acid oxidation by an oxidising igneous fusion.

Henriques fixed a reversed funnel —the shank of which had been cut off near the neck—over a deep porcelain capsule, and poured into this capsule

Fig. 103.—Battery of extractors for extracting resin, etc., from rubber (Altmann, Berlin).

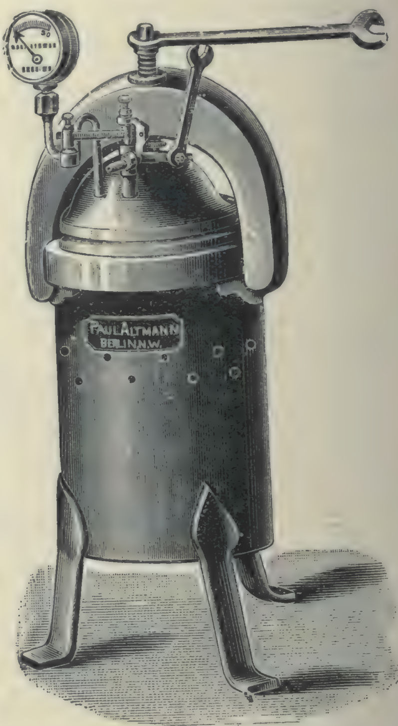


Fig. 104.—Autoclave used by Dittmas in analysis of rubber.

20 c.c. of pure fuming nitric acid (in the case of rubbers containing but little mineral matter, ordinary 60 per cent. acid, specific gravity 1·42, is sufficient), and into the acid, which is kept hot, by the orifice of the funnel, 3 to 4 grammes of the substance, cut up into very fine pieces, waiting before each addition until the brisk reaction produced has subsided, were introduced. When the reaction is particularly tumultuous, it is well to take the precaution to stop the upper aperture of the funnel by means of a second smaller funnel, the stem of which, cut off at the neck, should not dip into the liquid.

The first decomposition terminated, the whole is evaporated gently, on the water bath, to a syrupy consistency. Ten to 20 c.c. of nitric acid again added, and the bulk reduced to the same extent. To the highly concentrated liquid, add 4 grammes of a mixture of 3 parts of potassium nitrate and 4 parts of calcined soda, sodium carbonate. The whole is dried and cautiously ignited until tranquil fusion is effected. The mass should not be too alkaline, so as not to attack the enamel of the capsule, nor dissolve appreciable quantities of silica, alumina, and lime, which would affect the results of the analysis. With rubbers charged with graphite, prolonged fusion is required to burn off the carbon.[1] The fused mass is dissolved in hydrochloric acid, evaporated to dryness, to render silica insoluble, and redissolved in nitric acid. If all dissolves, it is diluted to a known volume and the sulphur estimated in an aliquot part, and the remainder used for the determination of the mineral matter. If a residue remain, it can only consist of silica, barium sulphate, and lead sulphate. It is digested with a fresh solution of ammonium acetate (obtained by supersaturatiug ammonia with 40 per cent. acetic acid). The lead sulphate dissolves quickly and completely. The insoluble portion is collected on the same filter through which the nitric acid solution was passed, to which the fresh liquid is added. If cloudiness ensue, which is frequently the case, it is made to disappear by the addition of 25 to 30 c.c. of nitric acid. It is diluted to a known volume, and the sulphur and oxides estimated as above.

There now only remain the residual insoluble silica and barium sulphate, which are separated by known methods. If barium sulphate be found in the residue, sulphuric acid or baryta may be found in the liquid, according as sulphur or baryta predominated in the rubber. This method has always given exact results, both for total sulphur and metallic oxides. When a rubber leaves little or no ash on the preliminary incineration, and if it be only required to estimate the sulphur, it will suffice to operate on 0·25–0·5 gramme of substance. Sulphur may also be estimated by Carius' process; but on account of the time required to seal the tubes, and the risk of rather frequent explosions, when more than 0·2 to 0·3 gramme of substance is operated on, it is preferable to operate as described. To ascertain the quantity of sulphur employed in vulcanisation,—not only the sulphur which serves for vulcanisation, but also the sulphur in excess remaining in the free state in the mixture,—it is necessary to deduct the total sulphur which may exist as sulphate and sulphide. Of all methods proposed for this purpose, only one is reliable: dissolving the rubber and the free sulphur in spirits of turpentine. This method yields accurate results, but is very long and inconvenient. The rubber must be digested in spirits of turpentine for six to eight days, at a temperature of 60° to 70° C. (140° to 158° F.). Moreover, this period does not always suffice. The end is accomplished more quickly by heating the spirits of turpentine to boiling, the sample is then dissolved in one or two days; but at that temperature sulphur acts on spirits of turpentine, and the sulphuretted hydrogen which is formed may act on the metallic oxides present and metamorphose them into sulphides, thus giving rise to erroneous results. But these are not the only drawbacks of this method. It is not economical, on account of the large quantity of spirits of turpentine required; and the filtration of the solution is always difficult, sometimes impossible. With a sample of rubber highly charged with zinc oxide, Henriques was not able by any scheming to obtain a limpid solution. The operation is always so protracted that the spirits of turpentine partially resinifies on the sides of the filter, and it becomes very difficult to remove it by lighter solvents, such as benzine, carbon disulphide, etc. Henriques therefore sought a substitute for spirits of turpentine, and found it in ordinary well-rectified petroleum spirit.[2] Heated above the melting-point of sulphur, petroleum spirit easily dissolves vulcanised rubber. Solution is completely

[1] But few chemists would make or recommend a short, far less a prolonged, alkaline fusion in a porcelain vessel.

[2] "Petrole ordinaire" of the author's is taken to mean "spirit."—Tr.

effected in one or two days. It will be observed that—1. Commercial petroleum spirit often contains a little sulphur, from which it is freed by repeated agitation with caustic soda, drying, and rectifying, collecting the portions passing between 140° and 150° C. (284° and 302° F.). 2. If the temperature rises above a certain limit, petroleum may be attacked by sulphur, but Henriques found that the action of sulphur on petroleum spirit may be neglected up to about 150° C. (302° F.). To avoid this error, it is only necessary to work below this limit. Five grammes (in the case of but slightly charged qualities, 10 to 15 grammes) of the sample are weighed into a tared $\frac{1}{4}$-litre flask and 150 c.c. of purified petroleum spirit added, and the whole heated in an oil bath at 140° to 150° C. (284° to 302° F.) until the rubber is disintegrated and dissolved, and the insoluble portions are deposited in the purverulent state. As control, a second flask is installed alongside the first, containing petroleum spirit and sulphur, in which the disengagement tube dips into a small wash-bottle containing acetate of lead. If the solution of lead does not blacken, it may be taken that the temperature has not exceeded the proper limit. Solution effected, it is allowed to stand in a warm place, and the liquid is decanted through a tared filter, washing once or twice by decantation, and then the residue is finally run on to the filter; the flask is again washed with hot petroleum spirit, and the washings filtered without detaching the insoluble particles adhering to the glass; the washing is finished with petroleum ether (*gasolene*), the flask dried, and filtration done at 110° C. (230° F.). The estimation of sulphur in the insoluble portion gives the amount, and qualitative and quantitative analysis determines the form in which the sulphur exists. The difference between the total sulphur and that found in the residue gives the sulphur added—*i.e.* (1) *the amount of sulphur used in vulcanisation* and (2) *the free sulphur*. It is necessary, however, to remove a possible error: the presence of oxidising agents, such as litharge, alkaline earths, or carbonates, may have rendered a portion of the sulphur insoluble by transforming it into sulphates or sulphides. Thus, Henriques found in a rubber, along with much chalk and oxide of lead, a small quantity of gypsum. It is scarcely possible that this salt was mixed in its natural state with the rubber, and it was more likely generated during vulcanisation itself. That is a point upon which chemical analysis alone cannot decide. The insoluble residue may be used for the quantitative analysis of metallic oxides, but it lends itself especially to a proximate analysis for the purpose of ascertaining the precise form under which these oxides have been employed. In the great majority of cases, not only can the total composition of a rubber be ascertained, but also the nature and the proportions, and even the degree of fineness, of the salts employed in the manufacture of the rubber in question. To determine the proportion of organic matter undissolved by petroleum spirit, different methods are pursued, according to circumstances. If all the metals have been determined, and all the latter give stable sulphates on ignition, the simplest method consists in calcining an aliquot part of the residue with sulphuric acid. The proportion of organic matter burnt is calculated from the weight of the sulphates and that of the salts from which they originated. The organic matter can also be deduced from the difference between the total residue and the total weight of the salts of which it is composed. If the latter be soluble in an acid, that again furnishes a convenient method of separating the insoluble organic matter; it is the method used to separate metallic salts from graphite, so often met with in door and stair mats. It is rare that pliant rubber leaves a residue insoluble in petroleum spirit. Those which contain substitutes sometimes dissolve with difficulty, but substitutes can be so separated that the remainder of the rubber dissolves without difficulty. This vehicle likewise dissolves the other organic substances, fatty oils, paraffin, asphaltum. As to the insoluble organic matter, *e.g.* cork powder, sawdust, etc., they have only a potential existence in technical treatises dealing with rubber and its applications. Henriques never met with them in any of the samples from every source which he analysed. But there is an important group of manufactured rubbers which do not dissolve in petroleum spirit, namely, the ebonites, which offer the greatest resistance to all

chemical reagents. These are dealt with in the sequel. The course of his researches led Henriques to experiment on the separation of rubber from organic make-weights. In chemical literature but sparse and inconclusive indications are found on this point, although the use of rubber substitutes, imitations, and organic make-weights is most extensive. There is not a class of natural products which has not been tried for this purpose; but the more the properties and the durability of rubbers so weighted were studied, the more was their manufacture abandoned. It would appear that now only one class of organic compounds play an important rôle in the industry. These are the products sold under the name of rubber substitutes, artificial rubber, or imitation rubber, made by heating oils with sulphur or sulphur chloride. Some non-sulphuretted substitutes, made by oxidising oils, are also encountered. This category of compounds appeared to Henriques to be worth examining. Substitutes are generally met with in the form of yellow or brown elastic masses, without cohesion, breaking up under pressure, greasy and moist to the touch. Two of these substances gave the following results:—

TABLE LXIX.—MOISTURE, SULPHUR, AND ASH IN RUBBER SUBSTITUTES.

	I.	II.
Moisture	1·00	0·85
Sulphur	6·17	6·4
Ash	5·51	0·8

The ash consisted of lime, alumina, with traces of iron oxide and silica. Substitutes behave towards solvents almost like rubber itself; insoluble in alcohol, they only dissolve with difficulty and incompletely in benzol, carbon disulphide, and spirits of turpentine, etc. To detect oils or fats in manufactured rubber, a method has been proposed which yields, in experienced hands, useful results. The rubber is digested in carbon disulphide to which 5 per cent. of spirits of turpentine has been added, the solution is filtered after a few hours, and distilled. An appreciable residue indicates the presence of foreign bodies of a fatty nature. The method has several drawbacks: first, vulcanised rubber is slightly soluble in the mixture of carbon disulphide and alcohol;[1] the experiment is not conclusive unless the fats are present in notable quantity; finally, free sulphur is likewise dissolved, and may give rise to error. Notwithstanding these drawbacks, for qualitative purposes, the method, applied with discretion, may yield useful indications. For a quantitative estimation the process cannot be adopted, because substitutes only dissolve partially, even when isolated and repeatedly digested in alcoholised carbon disulphide.[1] The sorts which were examined, in dissolving, gave up from 20 to 30 per cent. of their weight, and on each treatment afterwards still further lost 1 to 2 per cent., so that it cannot be admitted that substitutes are insoluble, and that it is the proportion of unchanged oil or fat which alone dissolves. Substitutes dissolve completely in petroleum spirit at a high temperature, as vulcanised rubber does itself. Ligroin[2] only dissolves them partially. Aqueous soda dissolves them with difficulty and incompletely. The action of alcoholic soda will be described further on. Hübl's iodine addition method seemed likely to yield indications, in its way, for rubber hardly absorbs iodine, whilst the sulphuretted oils should readily fix iodine, like the oxidised oils which almost retain their primitive iodine value. Preliminary experiment led to this unexpected result: sulphuretted oils do not absorb iodine and behave like quasi-saturated compounds. Henriques then tried to separate the sulphur from the substitutes and to isolate and weigh the regenerated fatty acids. He treated the substitutes with alcoholic soda, to which different

[1] There is here an obvious discrepancy as to the nature of the mixed solvent, whether it is alcohol or "turps" that is added to the CS_2.—TR.

[2] Intermediate between gasolene and petroleum spirit. Density 0·70–0·73 B.P., 110°–120° C. (230°–248° F.).—TR.

salts which ought to fix sulphur were added,—salts of lead, mercury, copper, and zinc; but in whatever way he operated, the fatty acids, isolated from the alcoholic lye in very variable quantity, always contained equally variable quantities of sulphur. He attempted, without any better success, to effect saponification and desulphurisation in a closed vessel at a high temperature, by replacing ethylic alcohol by amylic alcohol. However, it was found by these experiments that substitutes dissolve totally and without trouble in alcoholic soda, and on this property may be based at least an approximate method of analysis. To effect decided separations such as can, for example, be done in inorganic analysis, is impracticable in this field. Results can only be approximate, as we have to deal not with simple combinations but with very complex mixtures, like rubber itself, which may contain substances belonging to different classes of bodies. The following experiment shows that substitutes, or at least their organic constituents, are completely soluble in alcoholic soda. One gramme of substitute is boiled in a flask attached to a reflex condenser, with an excess of caustic soda (7 to 8 per cent. Na_2O). After a few hours the alcohol is distilled off, the residue dissolved in water, and filtered through a tared filter. Weight of the dry residue = 0·041 = 4·1 per cent.; weight of the ash = 0·0413 per cent. The residue, therefore, no longer contains any trace of organic matter. Another substitute which left no ash dissolved without residue. On the other hand, vulcanised Para rubber was treated similarly (sample A).[1] This sample yielded on analysis—Ash = 2·54 per cent.; sulphur = 7·12 per cent. Extraction by caustic soda gave—Dry residue = 94·9 per cent.; containing sulphur = 2·75 per cent. By difference we get in solution—Total substance = 5·10 per cent.; less sulphur (7·12–2·75) = 4·37 per cent.; organic matter dissolved = 0·73 per cent.

The result is not quite so fine as above figures would indicate. On incinerating the insoluble residue of the extraction, 8·4 per cent. of ash was found, say 7·7 per cent. on the original rubber. As the latter only contained 2·54 per cent. of ash, we get, after extraction, an excess of 5·16 per cent. of fixed substances. The ash of rubber, treated with alcoholic soda, is in great part soluble in water, has a strong alkaline reaction, and contains sulphates. It would appear that, as a result of treatment with alcoholic soda, rubber fixes a certain quantity of alkali separated by washing. The same occurred in all subsequent experiments and with all varieties of rubber. It is not practicable to separate the alkali from a rubber treated with alcoholic soda by boiling it with dilute acetic acid, not even with hydrochloric acid. An acid extraction would, moreover, complicate the analysis of the mineral matter; Henriques gave that up, and attributed the facts observed to the formation of an insoluble salt of sodium, at the expense of one of the constituents of the rubber. It must not be concluded from the fact that the residue insoluble in alcoholic soda was found to contain 5·16 per cent. of mineral matter, which did not pre-exist in the rubber, that the latter had lost an equal quantity of substance, as (1) the ash contains sulphur, the weight of which has to be deducted; then (2) this sulphur is present as sulphuric acid—the incineration having been done in this instance, as in every case, in presence of ammonium nitrate. For each part of sulphur in the residue $2\frac{1}{2}$ parts of SO^5 must therefore be deducted. To ascertain the amount of matter extracted from rubber by alcoholic soda, it is necessary (1) to estimate the ash; (2) to estimate the sulphur in the initial rubber; (3) to weigh the extraction residue; (4) to estimate the sulphur therein; (5) to incinerate it, and weigh the ash. To almost be certain of the results, it is necessary to make each experiment in duplicate, slight errors being liable to seriously affect the final result. Analyses of this nature are neither simply nor easily executed. To ascertain whether this method gave reliable results and yielded constant figures, Henriques repeatedly analysed another variety of Para rubber (sample B). The results are given in Table LXX.:[2]—

[1] By Para rubber is meant rubber containing only the sulphur added for vulcanisation, and not rubber from any particular source.

[2] All these results are brought to per cent. of the rubber.

TABLE LXX.—RESULTS OF REPEATED ANALYSES OF SAME SAMPLE OF PARA RUBBER (HENRIQUES).

	I.	II.	III.	IV.	V.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Ash	2·8	...	...	...	...
2. Sulphur	9·5	...	...	...	...
3. Extraction residue	...	95·40	95·00	95·55	95·55
4. Ashes of residue III.	...	8·49	9·02	9·21	9·17
5. Sulphur of residue III.	...	4·50	4·50	4·35	...
6. Dissolved sulphur	...	5·00	5·00	5·15	...
7. Sulphur in ashes IV.	...	...	1·14	1·24	1·08
8. Corresponding amount of SO_3	...	...	2·85	3·10	2·70
9. Na_2O in ashes (=4.—1.—8)	...	...	3·37	3·31	3·67
10. Real organic residue of extraction =(3.—9)	...	...	91·63	92·24	91·80
11. Hence: there were dissolved — sulphur	...	5·00	5·00	5·15	...
— organic matter	...	..	3·37	2·61	3·12

The agreement between the analyses is very satisfactory. The figures of V. were obtained by again treating the residue from extraction IV. with alcoholic soda. Nothing further was dissolved by the second extraction. The analysis was conducted as before: 3 to 5 grammes of the substance cut into small fragments were boiled in a flask attached to a reflux condenser (Fig. 103) for eight hours, with about ten times their weight of alcoholic soda, containing 6 to 8 per cent. Na_2O. The whole was then diluted with water, and the alcohol boiled off on the water bath, the residue collected on a tared filter, and carefully washed, dried at 100° C. (212° F.) until constant, and then weighed. The ash determination of the residue was always done with addition of ammonium nitrate, so as to make sure of converting all the sulphur into sulphuric acid. We may conclude that vulcanised rubber of the following composition—ash 2·8, sulphur 9·5, and rubber 80·7 = 100·0 per cent.—cedes on an average of alcoholic soda, sulphur 5·05 per cent., and rubber, 3·03 per cent.

Does it follow from these figures that the dissolved sulphur existed in the free state in the rubber, and that what remains in the insoluble is the chemically combined sulphur of vulcanisation? Henriques' experiments do not give a precise reply. That different Para rubbers (containing nothing but sulphur and rubber) leave variable quantities of insoluble sulphur on extraction does not upset this hypothesis; in fact, the quantity of combined sulphur may vary greatly with the temperature of vulcanisation and the whole of the conditions of manufacture. Samples A and B, the analyses of which have already been given, left—

TABLE LXXI.—SHOWING VARIATION IN RATIO OF INSOLUBLE SULPHUR TO RUBBER IN PURE VULCANISED PARA.

Per cent. of Rubber.	Per cent. of Insoluble Sulphur.
A with 90·34	2·75
B ,, 87·7	4·45

With reference to the organic matter dissolved, the proportion of which may vary according to the sample from 2 to 4 per cent., it may differ much in its nature. It probably consists of the vegetable oils and fats which all rubbers contain in small quantity. Another hypothesis presents itself to my mind, namely, that raw rubber would cede a portion of its substance to alcoholic soda, and that the portions dissolved originated in the portions of the rubber which had escaped

vulcanisation. The following results, obtained by treating 100 parts of dry and *purified* rubber, shows that this hypothesis is unsound :—

Table LXXII.—Effect of Treatment with Alcoholic Potash on Analysis of Pure Dry Rubber (Henriques).

	Per cent. of Initial Rubber.
1. Ash	0·32
2. Moisture	0·35
3. Extraction residue	98·04
4. Ash of residue II.	1·89
5. Na_2O in ash IV.	1·57
6. Hence dissolved	3·53

Alcoholic soda dissolves almost the same weight of organic matter in raw rubber as in vulcanised rubber. With hardened rubber (ebonite, *durci*) analogous results are obtained. Henriques found—

Table LXXIII.—Effect of Treatment with Alcoholic Soda on Analysis of Ebonite (Henriques).

	Ebonite A.	Ebonite B.
	Per cent.	Per cent.
1. Ash	0·01	0·05
2. Sulphur	31·20	40·12
3. Extraction residue	92·14	90·94
4. Ash of residue III.	3·87	6·99
5. Sulphur of residue III.	22·60	29·43
6. ,, dissolved	8·60	10·69
7. ,, of ash IV.	0·49	1·51
8. $=SO_3$	1·22	3·78
9. Na_2O in ash IV.	1·57	3·21
10. Real extraction residue	90·57	87·73
11. Portion dissolved { sulphur	8·60	10·69
organic matter	0·83	1·58

The portion of ebonite insoluble in alcoholic soda is more difficult to extract than in the case of pliant rubber. Thus sample B, after the first extraction of six hours, yielded, on a second extraction of the same duration, 0·8 per cent. of sulphur and 1·47 of organic matter. The following analyses show how the method is applied to the analyses of rubber sophisticated with substitutes. The insoluble extraction residue is treated with warm petroleum spirit, in which it dissolves completely; it, moreover, presents all the characteristics of pure rubber; as the whole of the preceding experiments render it possible to predict, the separation of the rubber from the substitute is complete.

What proportion of the total sulphur comes from the substitute? What quantity has been added for vulcanisation purposes? That, the method cannot tell us. Rubber substitutes dissolve in alcoholic soda, whilst natural rubber cedes only a minimum fraction of its ingredients with this restriction, at least in the case of the samples which Henriques was able to procure. Natural rubbers are so various, and the number of substitutes so great, that it would be rash to draw general conclusions from the analyses of a few samples. Henriques was the first to recognise that his conclusions would have gained in precision if they had been controlled by the analyses of mixtures, the composition of which had been made known to him by manufacturers. He spared no pains to secure this

Table LXXIV.—Analyses of Rubbers Sophisticated with Rubber Substitutes (Henriques).

	Quality A.	Quality B.
	Per cent.	Per cent.
1. Ash	1·90	3·00
2. Sulphur	5·10	4·26
3. Extraction residue	45·80	88·97
4. Ash of residue III.	5·31	5·87
5. Sulphur of residue III.	0·66	2·38
6. ,, dissolved	4·44	1·88
7. ,, of ash IV.	0·29	0·50
8. ,, as SO_3	0·72	1·15
9. Na_2O in ash IV.	3·12	1·62
10. Real extraction residue	42·68	87·35
There has therefore been dissolved { sulphur	4·44	1·88
There has therefore been dissolved { organic matter	52·88	10·77
There remains undissolved { sulphur	0·66	2·38
There remains undissolved { organic matter	40·12	81·97
There remains undissolved { ash	1·90	3·00

Table LXXIVa.—Composition Calculated of Rubbers whose Analyses are given in Table LXXIV. (Henriques).

	Quality A.	Quality B.
	Per cent.	Per cent.
Rubber	41·32	84·43
Substitute	51·68	8·31
Sulphur	5·10	4·26
Ash	1·90	3·00
	100·00	100·00

control; but there reigns, to a high degree, in the camp of rubber manufacturers, that mistrust and a mysterious way of hiding trifling things which the chemist still meets in those branches of industry where science has up to now found little or no opportunity of seeing her services put to the test.

Amongst substances most frequently used in the rubber industry, a place in the first rank must be given to the compounds sold under the most diverse names, which result from the action of sulphur, or of chloride of sulphur, upon oils—substances the whole of which are classed under the generic name of *substitutes* (*factices*). Two chief sorts are known in the trade—the whites and the browns; and, in fact, these kinds are altogether different from a chemical point of view. In a previous memoir, Henriques had already given an analysis of two kinds of white substitutes, reduced to percentage of water, moisture, and fixed ash. A more thorough examination of these same products has been made. Both are slight yellowish, clotted, elastic masses, with a neutral reaction and a slightly penetrating oleaginous odour. Water extracts nothing; acids and alkalies but little; neither do the majority of neutral organic solvents. The characteristic of these products is their high percentage of chlorine, almost as high as their percentage of sulphur. According to the behaviour of the products with solvents, the chlorine should exist in organic combination. If, as all facts indicate, and as the experiments detailed further on show, the substitutes examined result from the action of chloride of sulphur upon oils, that reagent has entered entirely (body-bulk), chlorine and

sulphur, into the molecule of the oil (fatty body). In order to facilitate the explanation of the results, the analytical data upon which the developments and conclusions of Henriques' work are based, are appended :—

TABLE LXXV.—ANALYSES OF COMMERCIAL RUBBER SUBSTITUTES (HENRIQUES).

	White Substitutes.			Brown Substitutes.	
	A.	B.	C.	A.	B.
Sulphur in the substitute	6·4	6·17	8·25	15·48	17·71
Chlorine ,, ,, ...	5·0	5·86	8·88	0·7	0·36
Water ,, ,, ...	0·85	1·0	...	...	...
Ash ,, ,, ...	0·8	5·51	...	...	...
Percentage of fatty acids . . .	90·45	73·58	...	...	...
Sulphur in the ,, ...	6·12	6·45	8·15	14·14	15·20
Chlorine ,, ,, ...	0·83	0·43	...	...	...
Iodine value of the substitute . .	30·9	31·0	32·6	42·0	42·0
,, ,, fatty acids . .	91·3	91·2	102·3	129·0	125·6

TABLE LXXVI.—ANALYSES OF SUBSTITUTES PREPARED FROM VARIOUS OILS (HENRIQUES).

	A.	B.	C.	D.	E.	F.	G.	H.	I.
Sulphur in the substitute .	9·34	4·78	8·28	6·59	7·68	..	4·82	10·6	6·23
Chlorine ,, ,, .	8·84	4·85	7·62	5·95	7·44	..	0·70	8·95	5·36
Water ,, ,, .	3·02	0·85	..	..	..	..	..	..	..
Ash ,, ,, .	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
Percentage of fatty acids .	79·6	81·67	86·89	87·95	74·90	..	85·35	..	..
Sulphur in these acids . .	9·88	4·06	8·34	6·54	8·32	..	5·32	..	6·44
Chlorine ,, ,, . .	traces.	0·60	little.	little.	..	..	0·20	traces.	traces.
Iodine value of the substitute	56·3	52·6	32·5	26·9	33·6	42·8	35·2	21·9	30·3
,, ,, acids .	160·3	141·2[1]	101·5	102·8	133·3	129·2	136·2[2]	143·5	91·5
Acetyl value	21·0	19·6	31·0	..	..	..	..	105·6	51·3

A, Raw linseed oil (fresh). B, Oxidised linseed oil. C, Rape oil (fresh). D, Oxidised rape oil. E, Oxidised poppy-seed oil. F, Mixture of oxidised linseed and poppy oils. G, Castor oil with a minimum dose of sulphur chloride. H, Castor oil with a maximum dose of sulphur chloride. I, The oil termed soluble castor (oxidised cotton-seed oil).

The determination of the sulphur of substitutes necessitates the same precautions as with rubber. Oxidation by nitric acid, followed by fusion with an alkaline oxidising agent, alone yields concordant results. To estimate chlorine, silver nitrate was added to the nitric acid, so as to avoid all loss by volatilisation of hydrochloric acid. After alkaline fusion, the whole is digested in water, the insoluble silver compounds are separated (generally metallic silver), and the sulphur estimated in one portion of the liquid as barium sulphate, and the chlorine by titration with nitrate of silver and sulphocyanate. Oils solidified by sulphur chloride only absorb insignificant quantities of iodine. Sample A, Table LXXV., gave an iodine value, according to Hubl, of 7·2. However, this value is only apparent. The feeble iodine absorption is partly due to the fact that the product is almost insoluble in chloroform. By frequently agitating the finely divided substitute in suspension in that liquid with an excess of iodine solution, and leaving it in contact for twelve hours, Henriques obtained from A and B, Table LXXV., iodine values of 30·9 and 31. Compared with the iodine values of the drying oils used to make these substitutes, these figures are still very low. Apparently, sulphur chloride

[1] Another determination gave iodine value = 121·0.
[2] Two other determinations gave 147·4 and 152·1.

partially saturates the free valencies of the oil to as great an extent by its chlorine as by its sulphur, possibly by its chlorine alone. Substitutes treated with iodine, in chloroformic solution, strongly retain the metalloid, and it is necessary to insist much in the back titration by hyposulphite, of stirring energetically and for a long time so as to destroy all the iodine in excess. It should be interesting to observe how substitutes behave on saponification. They are completely soluble in alcoholic soda. In this reaction the chlorine is almost eliminated, whilst the percentage of sulphur in the fatty acids corresponds exactly with the percentage of sulphur in the substitute. However, the proportion of fatty acids found is always lower than simple saponification would imply, even taking into account the elimination of the chlorine. Thus, sample A gave 90 per cent., sample B only 79·4 per cent., of fatty acids. A portion of the oil and a corresponding quantity of sulphur must therefore have undergone a transformation of a different order. The liquid from the saponification contains much chlorine but no apparent sulphur nor sulphuric acid, sulphuretted hydrogen nor sulphurous acid. But, on evaporating these liquids in presence of the excess of hydrochloric acid added to liberate the fatty acids to the point where hydrochloric acid fumes begin to be given off, the presence of much sulpuric acid is demonstrated. The sulphur chloride, with the aid of oxygen borrowed either from the air or the substitute itself, seems therefore to transform a portion of the oil into a sulpho-oleic acid analogous to those produced in the manufacture of turkey-red oil. In all the substitutes made by Henriques in the sequel, he demonstrates the formation, in greater or less quantity, of these sulpho-oleic acids, and a consequent diminution of substituted fatty acids. These concomitant reactions are difficult to regulate, for, even when working under apparently identical conditions, he obtained variable proportions of insoluble fatty acids.

As saponification eliminates chlorine from the molecule of the substitute, it was to be foreseen that the isolated acids would appreciably absorb more iodine than the substitutes from which they were derived, whilst the ordinary fatty acids yield an iodine value approaching that of the oils from which they were derived. The iodine values of the saponified acids are almost triple those of the substitutes. Little had been published on the action of sulphur chloride (S_2Cl_2) on fatty oils. The most recent communications are those of Bruce Warren[1] and Sommer.[2] Warren asserts that drying oils yield solid masses with chloride of sulphur, insoluble in carbon disulphide, whilst the non-drying oils yield products soluble in that solvent. Stolmann, in the last (German) edition of Muspratt's Dictionary, writes that these results merit but little reliance, because olive oil—the type of the non-drying oils—is transformed by the action of sulphur chloride into a mass analogous with rubber, insoluble in ether. The facts pointed out in Sommer's patent, as well as Henriques' personal experience, formally contradict Warren's assertions. If a sufficient quantity of sulphur chloride be added to a fatty oil, the two liquids soon mix. After a few moments of contact, energetic reaction sets in, accompanied by considerable disengagement of heat. The mixture froths, swells, gives off vapours of sulphur chloride, with a little hydrochloric acid, sulphurous gas, and after a few seconds becomes converted into a solid, elastic, scarcely tacky, amber-coloured mass, capable of being ground and crushed under the pestle. Exposed to the air, the mass loses the excess of sulphur chloride employed and the adherent hydrochloric acid; it then resembles in every respect the white rubber substitutes of commerce. If one or other of the reagents, or both, be diluted with a neutral solvent, carbon disulphide or benzol, the reaction is longer in being manifested, its violence is moderated, but the final result is the same. The substitute is a little more porous in consequence of the volatilisation of the solvent. That is how the reaction goes on in presence of a sufficient quantity of sulphur chloride. In the contrary case, along with a less disengagement of heat, a pasty, tacky residue is obtained, which even a long time afterwards, whether hot or cold, does not solidify.

[1] *Chemical News*, 1888, p. 110. [2] German Patent, No. 50,282.

TABLE LXXVII.—SHOWING HOW THE QUANTITY OF CHLORIDE OF SULPHUR REQUIRED TO TRANSFORM AN OIL INTO A SOLID SUBSTITUTE VARIES WITH THE NATURE OF THE OIL, ACCORDING TO HENRIQUES' EXPERIMENTS.

			Parts S_2Cl_2		Parts S_2Cl_2
100 parts of oil of	Linseed	do not yield a solid product with	25	but do so well with	30
	Poppy		30		35
	Rape		20		25
	Cotton		40		45
	Olive		20		25
	Castor		18		20

Inspection of these figures shows that there is no relation between the drying properties of oils and their aptitude to solidify under the action of sulphur chloride. Having thus fixed the required proportions of chloride of sulphur, Henriques prepared and analysed substitutes with a linseed oil, rape oil, and a poppy oil base, and with a mixture of equal parts of linseed oil and rape oil. The results are given in Table LXXVI. Neither of these are analogous with substitutes A and B of Table LXXV., products of English origin, of which it would be desirable to know the method of preparation. Indeed, the commercial sample C (Table LXXV., yielded, on analysis, figures so similar to those of the rape oil substitutes C, of Table LXXVI., that they may be rightly regarded as identical. The iodine values of the fatty acids isolated from substitutes present such wide differences from one kind to another that agreement in the iodine values may be taken as proof of identity. Moreover, Henriques learned from a manufacturer that the bulk of the substitutes made in Germany are made from rape oil. The distinctive characteristics of the English substitutes A and B are their relatively low percentage of sulphur and chlorine, according to which only 20 per cent. of sulphur chloride had been used to solidify the oil. With the exception of castor oil, Henriques demonstrated that only the *oxidised* oils can be solidified with that proportion of chloride of sulphur. Raw linseed oil, for example, which requires at least 30 parts of S_2Cl_2 to solidify it when it is fresh, only requires 15 to 18 per cent. when it has been heated for some hours at 200° to 250° C. (say 392° to 482° F.) in contact with air. If the temperature be pushed to 250° to 300° C. (482° to 572° F.), 10 per cent. of S_2Cl_2 suffices. A substitute prepared in that way would run into 4·78 per cent. of sulphur and 4·85 per cent. of chlorine. All drying oils behave in this respect like linseed oil. By pursuing this method, Henriques identified the English substitutes with the product obtained by the action of sulphur chloride on oxidised cotton-seed oil, known in the English trade under the name of soluble castor oil (lardine). *Brown substitutes* will be dealt with more briefly. They are met with in commerce sometimes as deep brown, tacky blocks; sometimes in powder. Analysis shows the presence of a much greater quantity of sulphur than in the substitutes previously examined. But chlorine is almost entirely absent. These substitutes are certainly obtained by heating oil with sulphur. They also dissolve in alcoholic soda; the soap, treated by an acid, disengages appreciable quantities of sulphuretted hydrogen; the isolated fatty acids, however, contain a smaller proportion of sulphur than the substitutes from which they were derived. The iodine values of these substitutes and those of the fatty acids are rather high, which induced Henriques to believe that it is linseed oil, or a mixture of linseed and rape oil, which is used in their manufacture. He did not pursue the examination of these substitutes, which are much less interesting, from the scientific point of view, than the previous ones. It was interesting to ascertain whether the vulcanisation of rubbers, sophisticated with substitutes, influenced the percentage of chlorine in the product. Henriques examined a number of manufactured rubbers containing substitutes, and always detected chlorine in appreciable quantity. As no other chlorinated compounds are employed in the manufacture of rubber—with one exception—we may conclude that the presence of chlorine in the alkaline

alcoholic extract of a rubber is due to the use of a white substitute. Quantitative tests, however, showed that the proportion of chlorine in manufactured rubbers is much less than that which corresponds with the quantity of substitute added. Thus, in two samples the percentage of substitute of which came out at 53 and 12 per cent., Henriques only found 0·5 and 0·37 of chlorine, whilst calculating on an average of 7 per cent. chlorine in the substitute he ought to have found 3·7 and 0·9 per cent. Cl. On vulcanisation, a portion of the chlorine is therefore disengaged either under the form of sulphur chloride or as hydrochloric acid, or in some other way. If alcoholic soda extracts an appreciable quantity of substance from a sample of rubber, and the extract contains no chlorine, the question is, whether the rubber is mixed with brown substitute or contains a fatty body. The fatty acids liberated from substitutes contain a rather smaller proportion of sulphur than the substitutes themselves. Those of brown substitutes generally contain more than 10 per cent. If, therefore, the fatty oils have not fixed sulphur during vulcanisation,—if they have not by the heating itself of the rubber been transformed into substitute, we should be able, by isolating the fatty acids from the treatment with alcoholic soda, and by estimating their percentage of sulphur, to distinguish between the addition of an oil heated with sulphur and an ordinary oil. To solve this point experimentally, Henriques heated rape oil with an excess of sulphur for several hours at a temperature of 130° to 135° C. (266° to 275° F.), the highest temperature reached in vulcanisation. The oil then dissolved large quantities of sulphur, which for the greater part re-crystallised out on cooling. After filtration the limpid oil was saponified, and the fatty acids separated in the usual way. Finally, the latter were dissolved in 90 per cent. alcohol, to separate the precipitated sulphur, and the sulphur was estimated in the acids thus purified, in which were still deposited some crystals of sulphur after filtration. Found sulphur = 0·98 per cent. The quantity of sulphur so found may be neglected, when compared with that which brown substitutes contain. The problem to detect the presence of white substitute in rubber, brown substitute, or in an ordinary fatty oil, and to estimate them therein, may therefore be regarded as solved. The presence of appreciable proportions of chlorine points to the addition of white substitute. The estimation of the sulphur in the fatty acids liberated from the alcoholic soda extract decides between brown substitute and a fatty oil. The method is inapplicable if a rubber contains all these three categories of substances simultaneously, but evidently that only occurs very rarely. What is to be understood by "patent rubber"? In Muspratt's Technical Dictionary, fourth (German) edition, it is said that the term is applied to those vulcanised rubbers the excess of sulphur in which has been removed by boiling in caustic alkaline lyes. This assertion is altogether erroneous. By patent rubbers is always meant those which are prepared from cut sheet, or the English sheet, cut by the saw from blocks of normal rubber. The method of making these sheets is known. The well-purified rubber is agglomerated in a masticating mixer into cakes of 3 to 5 kilogrammes (say 6½ to 11 lb.). A certain number of these cakes are amalgamated into a large block by means of a hydraulic press. This large block should be brought to such a decree of hardness that it can be divided into sheets of any thickness. Formerly, this object was obtained by abandoning the blocks for several months in cool cellars. At the present day, without doubt, artificial cold, to which the blocks are exposed for some days, is alone used for this purpose. The characteristic of the English sheet is the striated aspect which it owes to the action of the saw, and which every one has seen in good quality pliant rubber, used for surgical or scientific purposes. It would, however, be risky to admit that all rubbers which show the striæ of which we speak have actually been obtained from the cut sheet, because it is not difficult to obtain the same appearance by calendering the rubber, made in the ordinary way, between rolls carrying grooves which imitate on the sheet, while it is still soft, the imprints left by the saw. Objects made from English sheet are almost always vulcanised in the cold by sulphur chloride. A small proportion only is vulcanised by the old process of immersion

in a bath of molten sulphur. It would be interesting to complete this examination of the analysis of rubber and substitutes by the analysis of rubber vulcanised according to Parkes' process. It would be necessary to know, on the one hand, if this rubber also resists the action of alcoholic soda, and if the above method of analysis applies to rubbers vulcanised in the cold. On the other hand, it would be interesting to know if sulphur chloride acts upon rubber as upon oils, and fixes itself on the molecule of hydrocarbide by its chlorine and its sulphur at one and the same time. Henriques analysed numerous samples of patent rubber, and generally found more sulphur than chlorine. The following are some of the results obtained. He first cut as thin sheets as possible out of a block of pure dry Para, which he treated with chloride of sulphur. The analysis gave—

TABLE LXXVIII.—RESULTS OF ANALYSES OF PURE PARA RUBBER TREATED WITH SULPHUR CHLORIDE.

	I.	II.
1. Ash of the initial rubber	0·46	0·46
2. Sulphur	5·19	0·50
3. Chlorine	5·61	0·57
4. Matter extracted by alcoholic soda	2·90	2·20
5. Ashes contained in residue	0·67	0·90

Alcoholic soda therefore no more attacks rubber vulcanised in the cold than rubber vulcanised in the ordinary way. The method of analysis is therefore applicable to both of these commercial sorts. Sample I. was supervulcanised almost hard and barely elastic. Sample II., on the contrary, was insufficiently vulcanised, and at 100° C. (212° F.) had already become tacky. These analyses, therefore, represent limited sorts. Henriques procured, on the other hand, authenticated English sheet, which he analysed before and after vulcanisation—

TABLE LXXIX.—ANALYSES OF ENGLISH CUT SHEET PREVIOUS TO AND AFTER VULCANISATION BY SULPHUR CHLORIDE.

	English Sheet.	
	Normal.	Vulcanised.
	Per cent.	Per cent.
1. Ash	0·18	0·18
2. Sulphur	...	1·07
3. Chlorine	...	0·89
4. Alcoholic soda extract	1·94	1·66
5. Sulphur in extract IV.	...	0·57[1]
6. Chlorine in extract IV.	...	0·55
7. Dissolved rubber (by difference)	1·94	0·54

It would be expected that these patent rubbers of commerce would behave in an analogous manner when treated with alcoholic soda. Books dealing with the indiarubber industry repeat, in fact, that patent rubber cannot be cut except from blocks of good quality Para. Great was Henriques' astonishment

[1] All these figures are brought to per cent. of initial substance.

to find anticipations deceived by a great number of samples like the following, for example—

Table LXXX.—Analyses of Commercial Sheet Rubber.

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
1. Ash	0·67	...	0·20
2. Sulphur	3·68	2·37	1·86
3. Chlorine	3·63	2·51	1·33
4. Extraction residue	84·30	92·10	94·50
5. Ash in residue IV.	1·80	...	0·88
6. Sulphur in IV.	1·92	1·77	0·83
7. Chlorine in IV.	1·31	1·54	1·17
Soluble matter S + Cl	4·08	1·57	1·57
Soluble matter organic (about)	12·50	6·50	5·00

Sample I. was a cheap quality of North German manufacture. Samples II. and III. were rubber tubings of unknown origin. To ascertain the nature of the soluble product in sample I., 50 grammes of this substance were extracted by alcoholic soda, the alcohol evaporated, the liquid acidulated and taken up by ether. The latter abandoned an apparently oily residue, containing sulphur, 6·29; chlorine, 0·35; iodine value, 92.

The analogy of these figures with those previously obtained in the analysis of ordinary rubber sophisticated with white substitute did not appear to leave any doubt as to the presence of a similar substitute in the patent rubber examined. Henriques, moreover, learned from a manufacturer, that for some years back it is not rare to meet with cut sheet containing substitutes sometimes to the extent of one-third. It seems desirable to point this out, as many people are still persuaded that in buying cut sheet or patent rubber they will get pure rubber. The above analyses show how far this way of thinking is from being justified. The author has been able to control the results of his method by applying it to the analysis of manufactured rubber made by a rubber manufacturer with known proportions of white or brown substitues or colza oil. He has simplifed and improved his method so that it takes much less time and requires fewer precautions than at the outset. "I have found," says he, "that rubber treated with alcoholic or aqueous soda retains a non-neglectable quantity of alkali, the weight of which must be determined so as to add it to that of the dissolved substances obtained by difference (see preceding). This is not all. To the dissolved substances, it was necessary to estimate the sulphur in the initial sample and in the extraction residue. In washing the extracted rubber by boiling it with dilute hydrochloric acid, and washing until neutral, the quantity of alkali retained by the rubber is so small that in calculating the results it may be neglected." The complete analysis of a mixture of substitute, fatty oil, rubber, and sulphur comprises the following six determinations: (*a*) total sulphur; (*b*) total ash; (*c*) weight of the substance extracted by alcoholic soda; (*d*) weight of the sulphur in the extract (*c*) calculated to the sample analysed; (*e*) ash of the extract calculated to the sample analysed; (*f*) sulphur of the fatty acids (dissolved). To determine *c*, 1½ to 2 grammes of the substance are sufficient. In general, the extraction may be considered as finished after two or three hours' boiling with a reflux condenser with alcoholic soda. But it is well to renew the extraction from one to two hours with fresh lye, for the sake of precaution. Even the small quantity of the rubber itself which dissolves in alcoholic soda is taken into account by deducting from the alcohol extract 2½ per cent. of the weight of the rubber found by difference. This correction is the result of the average of ten determinations, the results of which varied between 0·9 and 3·5 per cent. Having the six

results indicated, the percentage of fatty acids (y) in the mixture, sulphuretted or otherwise, and the percentage of rubber (x) are obtained by means of the equations—

$$\frac{2 \cdot 5x}{100} + y = 100 - c + (e - b) - (a - d)$$
$$x + y = 100 - (a + b);$$

from which it follows—

$$x + \frac{100}{97 \cdot 5}(c - d - e)$$
$$y = 100 - (a + b + x).$$

The following results were so obtained in the case of three kinds of rubber, the composition of which was given by the manufacturer :—

Table LXXXI.—Analyses of Vulcanised Rubber containing Substitutes.

	I. Rubber with Brown Substitute.	II. Rubber with White Substitute.	III. Rubber with Oil.
	Per cent.	Per cent.	Per cent.
(a)	19·46	11·38	21·55
(b)	0·72	0·40	0·40
(c)	68·37	67·68	63·40
(d)	2·64	1·51	3·06
(e)	2·70	2·81	3·17
(f)	16·60	9·27	3·20
Chlorine . . .	Nil.	Very strong reaction.	Nil.

From which we calculate the composition—

Table LXXXII.—Composition of Rubbers whose Analyses are given in Table LXXXI.

	I.		II.		III.	
	Found.	Indicated.	Found.	Indicated.	Found.	Indicated.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sulphur . . .	16·13	16·4	9·19	9·6	21·55	23·5
Brown substitute .	18·50	19·3	...	...	...	...
White substitute .	...	...	25·43	25·8	...	...
Oil	...	...	...	...	20·42	17·7
Rubber . . .	64·65	64·3	64·98	64·6	57·63	58·8
Ash	0·72	...	0·40	...	0·40	...
	100·00	100·00	100·00	100·00	100·00	100·00

The agreement is very satisfactory. Henriques likewise sought methods of estimating *asphaltum* or *bitumen*, a substance which is very often met with in pliant rubber and ebonite. The usual solvents capable of dissolving asphaltum without residue, chloroform, spirits of turpentine, for example, swell non-vulcanised rubber into a porous mass, which renders all separation impossible. Nitrobenzol has not this drawback, and easily dissolves bitumen. On that fact the following method is based. One gramme of the sample to be tested, as finely divided as possible, is placed in a test-glass on foot, to digest with 30 c.c. of

nitrobenzol. After an hour in the cold, the whole is thrown on a filter, and the fragments of rubber pressed against with a glass rod, and washed with 30 c.c. of the same solvent. The contents of the filter, expressed as far as possible between folds of filter paper, are washed, by means of the wash-bottle, into a capsule; water added and boiled until all smell of nitrobenzol has disappeared. It is again brought on to a tared filter, washed, dried, and weighed. When the rubber is charged with mineral substances, the particles of which become detached on boiling, or partially dissolve, the contents of the capsule are evaporated to dryness, after elimination of the nitrobenzol. By so treating several kinds of non-bituminous rubber a loss was found of 1·44, 2·03, 1·10, 1·54 per cent., say an average of $1\frac{1}{2}$ per cent. By allowing for the correction resulting from this partial solubility of rubber itself in nitrobenzol, if we analyse a mixture containing only non-vulcanised rubber and asphaltum, supposing x to be the percentage of rubber in the mixture, we get—

$$\frac{1 \cdot 5 \times x}{100} + 100 - x = a.$$

In applying the process to the analysis of vulcanised rubbers, matters become a little more complicated by the presence of free sulphur, a portion of which dissolves in the nitrobenzol. But if such sulphur be eliminated beforehand, the results become normal. The extraction of the sulphur is best effected by the alcoholic soda used to dissolve the substitutes and the oils. It suffices, therefore, to proceed to the estimation of the asphaltum on the sample which has been used to determine the substitute. (Before filtering the liquid resulting from the extraction by alcoholic soda, it is necessary to eliminate all the alcohol, as already recommended.) Henriques found that asphaltum itself, under these circumstances, only suffers a neglectable loss of weight, 4 to 5 milligrammes for 1 gramme, whilst several vulcanised rubbers, previously desulphurised by alcoholic soda, washed and dried, subjected to the same treatment, lost 2·7, 2·33, 4·11, 3·51 per cent. of their weight, say an average of 3 per cent. This figure may be taken as the coefficient of solubility of vulcanised rubber in nitrobenzol. It is allowed for in calculating the analysis. The process was applied to four mixtures, in known proportion, of vulcanised rubber and asphaltum. It gave the following results:—

TABLE LXXXIII.—ANALYSES OF RUBBER MIXTURES CONTAINING ASPHALTUM DETERMINATION OF ASPHALTUM THEREIN.

	Ingredients of Mixture analysed.		Loss on Desulphurising.	Loss on treating the Desulphurised Sample with Nitrobenzol.	Percentage of Asphaltum.	
					In the Desulphurised Sample.	In the Original Sample.
			Per cent.	Per cent.	Per cent.	Per cent.
A	Rubber and sulphur Asphaltum . .	90·00 10·00	8·40	14·18	11·53	10·57
B	Rubber and sulphur Asphaltum . .	80·00 20·00	5·89	23·05	20·68	19·45
C	Rubber and suphur Asphaltum . .	77·27 22·73	6·84	26·48	24·20	22·54
D	Rubber and sulphur Asphaltum . .	71·46 28·54	4·86	31·46	29·34	28·05

The process is also applicable to the analysis of ebonite. The coefficient of solubility in nitrobenzol would appear to be a little smaller in ebonite than in that of pliant rubber. The loss in the case of three kinds of pure ebonite—rubber, sulphur, and mineral vulcaniser—was 1·59, 3·22, 2·22 per cent. Still, in the

absence of more experiments upon this point, 3 per cent. may be taken as the solubility of ebonite desulphurised by alcoholic potash. The analysis of an ebonite consisting of 80 per cent. of rubber and sulphur and 20 per cent. of asphaltum gave—

Table LXXXIV.—Analyses of Ebonite containing Asphaltum.

Weight on Desulphurising.	Loss on treating the Desulphurised Sample with Nitrobenzol.	Percentage of Asphaltum in the Desulphurised Sample (2 per cent. for the Rubber).	Percentage of Asphaltum calculated on the Original Sample.
Per cent.	Per cent.	Per cent.	Per cent.
5·96	22·50	21·01	19·76

Artificial asphaltum, made from coal-tar pitch, dissolves completely in nitrobenzol, like natural asphaltum.

Pontio's scheme for analysis of Rubber based on Henriques' & C. O. Weber's Methods.—Pontio, like Weber, separates the constituents of rubber into four groups, each of which has its own characteristic solvent—(1) *the absolute alcohol group*, comprising free sulphur, rosin, paraffin, oils, and fats; (2) *the alcoholic soda group*, substitutes, sulphur combined with substitutes; (3) *the acetone-lavender group*, mineral oils, bituminous products; (4) *the cumol group*, rubber and sulphur combined with rubber, mineral matter, and free carbon.

The first and fourth group separation may be used for natural unmixed rubbers, and would be of great use in buying. The whole four groups are necessary for black and grey, red and white rubbers. The fourth separation could be replaced by estimating the mineral matter by direct ignition, the rubber and vulcanisation sulphur being then got by difference; but this mode of operation is impossible when the presence of vermilion, free carbon, or free sulphur is suspected, and in that case the whole four groups must be worked through. Absolute alcohol, employed for the determination, by difference, of free sulphur and resins, is a fairly good solvent for the purpose; 100 parts of absolute alcohol dissolve in weight 0·425 grammes of sulphur, or 700 c.c. or 555 grammes of absolute alcohol can dissolve 2·360 grammes of sulphur. As 700 c.c. 555 (grammes) is the quantity necessary for the simultaneous determination of resins and free sulphur for four sample trials of 0·500 grammes each, it will be seen that for each sample this corresponds to 0·590 grammes of sulphur, a weight greater than the sample taken. As manufactured rubbers contain generally a maximum of 10 per cent. of sulphur with a minimum of 6 per cent. of which two-thirds are combined, it will be seen that there remains a margin quite large enough for determining the remaining free sulphur; the same liquid can therefore serve for two series of four samples. The imitations and the sulphur combined with them can be estimated without difficulty by alcoholic soda, as Henriques recommended. But, after the free sulphur has been eliminated by absolute alcohol, and the sample treated with alcoholic soda, the residue from the alkaline extract may be used to estimate, quantitatively, the sulphur combined with the substitutes. This method only applies to samples treated separately; but as this estimation is only of relative importance in most cases, it is estimated by difference. The bituminous matter and the unsaponifiable products should only be estimated with the acetone-lavender, after treatment with alcoholic sodium hydrate, for the imitations are slightly soluble in this mixture, whilst asphaltum and mineral oils do not dissolve in alcoholic soda. Pontio uses a peculiar digestor-lixiviator, constructed by G. Fontaine of Paris. This apparatus comprises a heated 2-litre flask containing the alcohol and solvents. This flask was originally surmounted by a series of bulbs, each of which carries a watering rose,

where the sample is placed. A gibbet with four corresponding small baskets is placed directly over the bath of hot alcohol. Above these bulbs is a condenser in which the alcohol vapours are condensed, and from whence they fall back into the flask, after having rewashed the samples placed in the bulbs; eight samples can thus be treated at once. Pontio has lately altered the construction of his extractor so that twelve samples can now be treated at once. It now consists of two superimposed receivers of hard glass, of a blown glass arrangement and a Soxhlet condenser. The lower vessel is a digestion flask fitted with a stopper forming a cork, in the centre of which are adjusted (1) the ground stem of the upper vessel (the lixiviator); (2) a support to hold six funnels. Inside the lixiviator there are adjusted in the centre of a second ground stopper six "roses," fitted with hooks on which to fix the funnels. Each "rose" is surmounted by an elbow forming a tube, which connects it with the condenser through a ground aperture. *Method of working.*—Remove the stopper from the apparatus, place it on a support so as to fix the samples in the special funnels and hang them on the bracket hooked into the lower aperture of the lixiviator, grease the stopper with vaseline in its ground part, and insert stopper after introducing necessary solvent.

1. *Method of operating—Absolute alcohol group—Determination of free sulphur, resins, and paraffin.*—Weigh out 0·500 gramme of finely divided rubber, place in the bottom basket, heat the sand bath, and let the boiling alcohol act during six hours. The sample is then raised into a higher bulb in the old apparatus and underneath one of the circular battery of "roses" in the newer design, where it is washed by the condensed alcohol vapours. The washed products are then placed with their funnels in the carbonic acid oven, and maintained at a temperature of 115° C. for two hours, and, after cooling under a desiccator, each sample is weighed. The difference in weight gives the sulphur, resins, paraffin, and water contained in 0·500 grammes of the product under analysis.

2. *Alcoholic soda group—Substitutes and substitutes combined with sulphur.*—The solid residue left from the preceding operation is allowed to digest in limpid alcoholic soda (8 per cent. of NaOH in 95 per cent. alcohol). After digesting for six hours it is removed, together with the funnel containing it, washed in boiling water until completely neutralised, and then with hot alcohol. It is dried at 115° C. and afterwards weighed. After checking the losses due to determination of the preceding elements, the difference in weight indicates the quantity of substitutes and of sulphur combined with these, contained in 0·5 gramme of the sample.

3. *Acetone-lavender group—Bituminous products, mineral oils.*—The residue left from the two preceding groups is again placed in a funnel and allowed to digest in the boiling mixture of acetone-lavender (40 per cent. of essence of aspice, dextrorotary lavender, and 60 per cent. of acetone) for the same number of hours. The above manipulations are then repeated, and the loss of weight gives the weight of the elements soluble in this mixture, *i.e.* the asphaltum, the unsaponifiable oils, etc., plus those soluble in alcoholic soda, which are to be deducted from the total loss.

4. *Petroleum-benzine group—Rubber and sulphur combined with rubber—Inert matter.*—One or several fresh samples are now taken of 0·500 gramme each. These are placed on specially dried filter papers (selected Schleicher; diameter 7 centimetres) that have been previously freed from grease by the solvent employed for the determination. About 10 to 12 milligrammes per filter paper are regularly lost in this washing. The solvent employed is cumol vapour. The sample is first placed, as already said, in a tared filter of 8 c.c. diameter containing a known weight of china clay (washed and calcined). The folding of this paper is of vital importance. There must be no adherent surfaces to avoid capillary ascension. The paper is first folded in two, then quartered, the inner fold is brought back once upon itself by folding it again into two, then a horn is made as on a carte de visite. The parts in contact are then separated by a forceps or the blade of a knife. After introducing the kaolin, the paper is moistened with a few drops of cumol and

the kaolin laid in the bottom of the filter. That done, the filter is furnished with its platinum wire support and the whole suspended about 1 centimetre above the top of the liquid, the cumol is boiled, and after twelve hours' digestion the samples are withdrawn and washed, first with crystallisable benzol from a wash bottle and then with boiling 95 per cent. alcohol. They are dried at 115° or 120° C., and then weighed. The solid residue is composed of mineral salts, free carbon, vegetable débris, etc. The part dissolved contains the pure rubber and the sulphur combined with rubber. The mineral matter may be determined by igniting the sample in closed capsules; the muffle should not, however, be heated above a dull red until all smoke disappears, when the lids are removed and the capsule so arranged that its bottom is not in direct contact with the muffle, which ought only at this moment to have reached a dull red heat. When the carbon on the sides of the capsules has disappeared, the residue is weighed. The ashes after cooling under the desiccator are weighed. This method is not so perfect as the solution method. M. Pontio afterwards gives the complete results of the analyses that he has carried out by this method, which, although not possessing the exactitude of certain more complicated methods, is amply sufficient for all practical purposes. He also publishes the processes he has employed for separate determination of sulphur in the different states in which it occurs in manufactured rubber. As above stated, he has altered (*Bull. de la Soc. Chim.*, 4 Ser. t. 5, p. 428, 1909) the design of his lixiviating digester, so that the roses with funnels underneath each are arranged in a circular battery form, their number being increased to six, and made several other modifications in his processes. But we cannot afford further space to his methods, except to remark that his group 4 solvent is now cumol vapour, and that a layer of about 2 grammes of china clay is placed in an 8 c.c. diameter filter in which the sample is placed in the extracting funnel.

Some years ago, Dr. Schultze of London claimed that the greater number of the prejudices against the use of substitutes are unfounded. Dr. Axelrod, Chief Chemist of the Kabelwerk-Oberspree, near Berlin, also urges that the same is the case with brown floating substitutes, and that these substitutes are not oxidised by atmospheric oxygen, and the perishing of the rubber need not be feared from that cause. Further, it need not be made a grievance against substitutes that they contain free non-saponifiable oil; on the contrary, this oil which may exist with a percentage of 35 per cent., facilitates the homogeneous distribution of the substitute in the rubber. One knows that the substitute will mix well with the rubber when it can be rolled into a thin transparent sheet. It is even advantageous, he urges, to have a larger proportion of oil than the above, in the case of certain mixtures. It may even be found up to 45 per cent.; acetone and hot alcohol easily extract this oil. As it is not oxidisable it plugs up the pores of the rubber, and the latter does not oxidise so readily. The same result may be obtained by the use of a certain amount of resin or paraffin. The following is a mixture for red washers:—

TABLE LXXXV.—MIXING FOR RED WASHERS.

	Per cent.
Manaos rubber	x
Golden sulphide	7
Flowers of sulphur	0·063x – 3·15
Brown floating substitute	96·15x – 1·063x

In the above formula, x may be taken as having a value between 90·44 and 50 per cent. The tensile strength will be higher the greater the amount of rubber used.

Nobel's Patent.—Patent No. 235,829, taken out by Mr. Nobel on the 26th

January 1894, for obtaining a new substance capable of being used as a substitute for rubber, as well as for gutta percha, leathers, and varnishes, of which the originality alone opens a new field of investigation to our research chemists, as well as to those in the trade always in quest of the new and the best :—By dissolving, in a substance which lends itself to the purpose, nitrocellulose, oxynitrocellulose, or hydronitrocellulose, products are obtained, the consistency of which is proportionate to the proportion of nitrocellulose effectively dissolved; it is in this way that celluloid is formed, which consists most generally of two parts of nitrocellulose for one part of camphor. Leaving decidedly explosive substances out of account, celluloid is the only substance thus obtained which can be utilised in industry. However, many attempts have been made to produce more or less analogous substances, but less rich in nitrocellulose, and capable of replacing rubber, gutta percha, leathers, as well as form utilisable leathers: even the substance patented in Britian in 1891 by Fredr. Crane, under the No. 3315, and which consists of sulphuretted oils, does not yield the results promised. It is for want of solvents really fulfilling the end in view that attempts have failed. My researches have enabled me to discover numerous solvents for nitrocellulose, oxynitrocellulose, and hydronitrocellulose, bodies which I shall hereafter call by the inclusive name of nitrocellulose, in proportions appropriate to the end in view—substances of such an elasticity and consistency that they may advantageously replace rubber, gutta percha, leather, and varnishes. To be suitable for the above-named purposes, a solvent should possess the following properties:—(1) It should dissolve nitrocellulose as freely and completely as possible, without there being, within the ordinary limits of temperature, either exudation or separation of the solvent, or want of plasticity of the product, or a tendency to become brittle. (2) It ought to enable products to be obtained which withstand moisture and direct contact with water. (3) It ought to be as little inflammable as possible, so that the product obtained be neither so explosive nor so combustible as to render its use seriously dangerous. (4) It ought to be fixed, or at least so little volatile, that the products obtained undergo no change in consequence of the gradual evaporation of the solvent. (5) It ought to have sufficient chemical stability, so that no spontaneous decomposition may take place. In order to find solvents for the production of the above-named substances fulfilling these conditions, I have had to search amongst substances unknown as solvents of nitrocellulose, for the above-mentioned purposes. They are enumerated below:—

1. The chloro and bromo, as well as the chloro- and bromo-nitro derivatives of camphor,—nitrocamphor, nitrocymenes, nitrotolulols, di- and tri-nitrobenzols, nitroxylols, nitrocumols, nitronaphthalines, nitranilines, as well as the chloro and bromo derivatives of all these substances; chloro- and bromo-nitrobenzol, chlorhydrins, acetins, acetochlorhydrins, and camphorins, nitrated rosin oils, in particular those obtained by the distillation of rosin soaps, as well as their chloro and bromo derivatives. Castor oil may be added to the above-named solvents, provided that it be not used to such an extent as to endanger the solubility, so that exudation occurs either on heating or cooling. 2. The above-mentioned solvents mixed or combined with one another.

By chloro and bromo derivatives I mean here, and throughout this descriptive memoir, chlorine and bromide addition, as well as substitution products. The solvents which are solid at the ordinary temperature should be melted or dissolved in a liquid solvent, so as to facilitate the incorporation of nitrocellulose with these solvents. As nitrocellulose is never a homogeneous substance, the most suitable kind for the purpose can only be chosen by experience, the more so as for economical or other reasons one solvent will be preferred to another, and because the best cellulose for one solvent is not always the best for another. But a slight preliminary test will easily determine whether the right degree of elasticity or consistency has been obtained. It is important to note that, with equal solubility, the least nitrated cellulose (obtained by direct nitration by weak acids, or by denitration by means of known processes of a strongly nitrated nitrocellulose) is to

be preferred, since by its use the inflammability of the product may be reduced to a minimum. Amongst these solvents the above-mentioned chloro and bromo derivatives are those which most attenuate the inflammability of the product. Nitrocellulose may be dissolved in, or incorporated with, the above-mentioned solvents, either in the moist or in the dry state. In the first case, incorporation with the liquid solvent, dissolved or melted, is very easily accomplished by mechanical mixing. In the second case, it is preferable to facilitate, by the addition of good volatile solvents, such as acetone, ether, alcoholised ether, methylic alcohol, ethylic acetate, the incorporation of the dry nitrocellulose. In both cases the substance should be mixed, either in a good mechanical mixer, heated by steam, or between the cylinders of a roller machine, likewise heated by steam, and the work should be continued until the substance becomes perfectly homogeneous and presents the desired consistency. If the final product be intended to be used at a temperature above the normal, the proportion of dissolved nitrocellulose ought to be increased, as the consistency of the product decreases in direct ratio with the temperature. It would be useless to specify here the great number of solvents which may be obtained by mixing or combining the above-named solvents, and I confine myself to enumerate below some good solvents which may serve as types :—

TABLE LXXXVI.—SOLVENTS CAPABLE OF BEING USED TO DISSOLVE NITROCELLULOSE CLAIMED IN NOBEL'S PATENT.

1. Five parts of nitrocumol, Three parts of mononitronaphthaline. 2. One part of nitrocymene, One part of nitrocumol, One part of mononitronaphthaline. 3. Bromocamphor. 4. Chloro- or bromo-nitrotoluol. 5. Chloro- or bromo-nitrocamphor.	6. One part of nitrated rosin soap oil, One part nitrocumol, One part mononitronaphthaline. 7. One part bromonitrotoluol, One part mononitronaphthaline, Two parts of nitrocumol, Two parts of nitrated rosin soap oil.

By dissolving in one of the above or equivalent solvents 15 to 20 per cent. of its weight of nitrocellulose, a very elastic mass is obtained, so much resembling rubber that it may be mistaken for it. Between 30 and 40 per cent. the substance approaches in properties more to the nature of gutta percha. If the nitrocellulose be still further increased, the product presents the appearance and consistency of leather.

If the solvent be very viscous, as is the case with the nitrated rosin oil, it requires much less nitrocellulose to be dissolved to obtain the same consistency than is used with very fluid solvents.

SECOND PART

GUTTA PERCHA

UNDER the name of gutta percha are described very diverse products, amongst which there is thus established a confusion which is very annoying and prejudicial to industry in general.

"It is of great interest to see light dawn on a question which up to now has been so obscure. The study of the botanical origin of those products which up to the present time have been grouped under the name of gutta percha is still but very little advanced, in spite of the works of numerous savants. It is necessary that the greatest efforts be made to establish the botanical origin of all the commercial varieties of gutta percha, and that as far as possible the methodical cultivation of the trees which yield good varieties be propagated and developed so as to prevent their disappearance."

DR. BEAUVISAGE, *Paris*.

HISTORICAL INTRODUCTION

If, on the one hand, France can claim the honour of being the first European nation to receive and utilise samples of *Indiarubber*, Great Britain, on the other hand, was the first European country to receive and utilise samples of *gutta percha*.

Gutta percha, which the native Malay race of the peninsula of Malacca, of the islands of Sumatra and Borneo, utilised from a very remote but undetermined epoch, was first introduced into Europe by the English traveller John Tradescant under the name of *Mazer Wood*. According to Obach, the first sample of gutta percha was brought into Europe by those "indefatigable travellers and curiosity hunters, the Tradescants, father and son, somewhere about the middle of the seventeenth century. On page 44 of *Museum Tradescantianum, or a Collection of Rarities preserved at South Lambeth neer London* (a small book by John Tradescant the younger, published in 1656), there is included in a list of such rarities as "Birds' nests from China," "Indian Fiddle," "Blood that rained in the Isle of Wight," and so on, a descriptive entry of a very interesting item, namely, "The plyable *Mazer Wood*, being warmed in water, will work to any form." This entry is believed to have referred to a sample of gutta percha, because no other substance, adapted for use as a raw material for making mazers or goblets, having the peculiar property of becoming plastic in warm water, and capable of being worked to any form, in the same way as the "plyable mazer wood," is known at the present day. What eventually became of this sample of "mazer wood" is unknown. The renowned Elias Ashmole obtained possession of the collection after the decease of the younger Tradescant, which occurred in 1662. The new owner removed the collection to Oxford to form the nucleus of the Ashmolean Museum, opened in 1683, but the historical sample in question is now neither at the Museum, nor at the Botanic Garden at Oxford.

In the year 1843, two rival candidates, both of whom were surgeons, and both residents of Singapore, claimed, each for himself, the honour of reintroducing gutta percha into Europe. One of those, whose name betokens Spanish descent, Dr. José d'Almeida, carried samples with him to London in the spring of 1843. These samples consisted of—(1) "a riding whip, made of the concrete milk of a tree indigenous in Singapore, called gutta percha by the Malays; also (2) a specimen of the concrete milk in the lump," with the remark that "it becomes ductile by being placed in hot water." The secretary of the Royal Asiatic Society appears to have acknowledged the receipt of the above specimens in a letter dated 8th April 1843, and to have handed for analysis a portion of the raw substance to Dr. J. F. Royle. It would also appear that Mr. W. C. Crane had previously received a similar portion, also for analysis, but from d'Almeida himself. But neither of these two gentlemen, entrusted with the samples for analysis, seem ever to have discharged the duty which devolved upon them. They apparently made no experiments, or at least no report on the samples with which they were entrusted, and, had it not been for the samples of the rival candidate having fallen into more discreet, skilful, and fortunate hands, it does not seem far from improbable that d'Almeida's samples would have shared the same fate as Tradescant's "mazer wood." In any case, no results were immediately forthcoming as the result of d'Almeida submitting his samples to the Royal Asiatic Society. Better fortune, however, attended the course pursued by the rival candidate to Dr. d'Almeida, for the

honour of reintroducing gutta percha into Europe. This was Dr. William Montgomerie, who, through the medium of his brother-in-law, Mr. H. Gouger, submitted samples to the Society of Arts during the summer of 1843. These samples consisted of—(1) "One bottle of the juice"; (2) "specimens of thin sheets resembling scraps of leather"; (3) "specimens of the substance formed into a mass by agglutinating the thin sheets, by means of hot water." In this instance, as already hinted, almost immediate results attended the submission of the samples. At a meeting, held on 30th November 1843, the Joint Committee of Chemistry, Colonies, and Trade took into consideration specimens of a substance called "gutta percha," from Singapore, sent to the Society by Dr. Montgomerie; and at a subsequent committee meeting, on 23rd January 1845, it was resolved "that this substance appears to be a very valuable article, and might be employed in great advantage in many of the arts and manufactures of the country." Again, at an ordinary weekly meeting of the Society of Arts, on 10th March 1845, Mr. Francis Whishaw, the secretary of the Society of Arts, described the specimens, and exhibited a piece of pipe, and a lathe band of gutta percha, which he had made therefrom, and which were afterwards on show at the Great Exhibition of 1851. Mr. Whishaw, not content with these practical demonstrations, covered the bottle, in which the milky juice was originally received, with gutta percha, softened in hot water. It is supposed to have been at this meeting that Mr. Christopher Nickles, as one of the audience, acquired his first knowledge of gutta percha, and so impressed was he with the intrinsic value of the product, that he induced Messrs. Wilkinson and Jewesbury, dealers with Singapore, to import a small trial order. Mr. (afterwards Sir) William Siemens first saw the product at the same meeting, and he, then and there, secured the samples, which he afterwards despatched to his brother, Werner Siemens, in Berlin, to test their suitability for insulating telegraph wires, a suggestion which has been attended, in the insulation of submarine cables, with results the effects of which cannot be over-estimated.

It followed as a natural sequence that the Society of Arts, having so promptly and efficiently assessed the value of gutta percha, and found several uses for it, awarded Dr. Montgomerie on 2nd June 1845, its gold medal. Montgomerie first became acquainted with indiarubber in 1822, when he acted as assistant-surgeon to the Presidency at Singapore. He then lost sight of it for twenty years, namely, until in 1842, when he noticed a parang or woodchopper, in the hands of a Malay woodman, the handle of which appeared new to him. His curiosity was still further aroused when he learnt that the substance had the peculiar property of becoming soft and plastic, like clay, in boiling water, and he at once possessed himself of the article, and asked the Malay to procure him as much of this substance as possible.

French writers assert that the first experiments in the use of gutta percha were not encouraging; English manufacturers, they claim, were not able to appreciate this very peculiar substance at its real value. But some of these samples were sent to Paris, where, on the data of Montgomerie, they were made into probes and other surgical instruments formerly made of rubber. Montgomerie failed to persuade the London surgical instrument makers to give it a trial. In 1845 Lagrénée brought back with him, on his return from an expedition to China, a certain quantity of gum plastic which he was able to secure during his passage through Singapore; he submitted it to the French Minister of Commerce. The substance put at the disposal of the French manufacturers was better examined, and in the following year, Alexander, Cabriol, and Duclos took out the first French patent for the use of gutta percha (28th July 1846).[1] This first patent is here given as a historical document. It shows, moreover, all the illusions which were readily conceived at the outset in regard to this new gum—illusions which were not long in being dispelled.

The Cabriol French Patent of 28th July 1846.—"It consists in lining both sides of a fabric of any kind of cloth, paper, or leather, with gutta in very

[1] But Hancock, Brooman, and Nickles had previously taken out British patents for utilising gutta percha.

thin sheets. For this purpose I place the stuff or fabric to be lined or waterproofed in a hermetically sealed vessel. The stuff having been thus got ready, I wind on two rollers the two sheets of gutta which are to be used to line the stuff. The rolls and the vessel are arranged in such a manner that the stuff as it comes out of the vessel unrolls itself, and is seized between the two rolls of gutta and is glued in between them. I then pass them to the hot rolls and heat the three united sheets, and I obtain a single, very consistent fabric, perfectly waterproof and homogeneous, fit for many purposes. In certain cases I suppress the intermediate fabric or core, and am satisfied with the fabric resulting from the superposition of the two sheets of gutta percha, superimposed in an inverse sense to the thread of the roller, pressed in the hot state." Gutta percha had taken its rights of birth amongst us, and a new industry was thus created. It is not intended to follow step by step the various phases through which this industry passed up to the moment when, its essential properties being better studied and better known, gutta percha took its definite place in the different applications to which it was thought it should be applied. It will suffice to say that, as a new product, it was employed for all the purposes first reserved for rubber. People became infatuated with it. Patents multiplied, one in emulation with another. Corks, cements, threads, slippers, surgical instruments, garments, pipes, sheathing for ships, were all made of it, and even boats were made wholly of gutta percha; and it is only necessary to read the reports of the regretted M. Ballard on the London Exhibition of 1851, to be convinced of the exaggerated enthusiasm incited by this new discovery. Of all these applications—more or less judicious—there now only remains but the memory, and if it were not for some quite special uses, the gutta percha of Sumatra would very soon have been abandoned by industry. In fact, the characteristic properties of gutta percha are such that they are opposed to all the uses to which it was put at first. An eminently plastic substance at a but slightly elevated temperature, it was natural to see garments as well as slippers made of this material soften with the heat of the fire when it was approached. It was attempted to correct this defect by vulcanisation, which had just imparted to rubber its real industrial importance, but there again they were deceived in regard to the real properties and the nature of the body which they tried to vulcanise. The action of sulphur and halogens upon gutta can in no way be compared to that of these reagents on rubber. The illusions, therefore, held in regard to this substance were only of short duration, and it was really to the special properties of gutta percha, and more particularly to its malleability at a comparatively low temperature, as was well said by M. Guibal in his report on the Exhibition of 1878, that the cause of the relative non-success of the new industry was due. It must not be imagined that gutta percha is a substance now little utilised and capable of being easily replaced. It is a very necessary substance indeed, and its discovery, as well as the study of its properties, occurred at the psychological hour (at the right time), and that it was thus enabled to find its true place in industry. Suppose gutta percha had been put on the international market simultaneously with rubber, it is evident that at that moment, when dynamical electricity, electro-metallurgy, as well as the real scientific work of chemical, medical, and photographical laboratories were hardly known, gutta percha would have been relegated to the class of substances of but little importance, and assuredly Seligmann Lui, Beauvisage, Serrulaz, Burck, and ever so many others, would not have been sent to the Indian Archipelago to search for gutta percha, nowadays regarded as indispensable to international life and transactions. Discovered, on the contrary, at the moment when dynamical electricity had already commenced to play a rather important rôle, the insulating properties of gutta, its extraordinary plasticity, and finally its inalterability in water, or, better still, in salt water, were very soon perceived, and thus gutta percha came to be used in the making of telegraph cables (Patents of W. H. Barlow and Th. Forster, 1847, and E. W. Siemens, 23rd April 1850). Wheatstone, who from 1837 had tried to connect England telegraphically with the Continent, had perceived the advantages

presented by wires covered with gutta percha, but his idea was not realised by Walter Breit, who, on the 10th January 1849, immersed the first submarine cable at Folkestone of two miles in length. In the interval, gutta percha had been used for the preparation of moulds intended to reproduce designs of very fine delicacy by electro-metallurgical processes. The resistance which gutta percha presented to acids was likewise taken advantage of in the making of vessels, funnels, and tubes, the use of which has become general in chemical manufacture, in photography, and in laboratories. The medical art has, in fact, found in it a precious auxiliary in the manufacture of a great number of surgical instruments. Gutta percha has therefore only changed its employment; but, in spite of the fact that this substance was very soon only used sparingly, and that the immoderate waste in the beginning has ceased, its use has none the less assumed such an extension that the limited resources which nature presents to us, under this head, would appear to be likely to be exhausted in the near future. The governments of all civilised nations are therefore justified in becoming alarmed at this state of affairs, more so that the Malays and Papuans, more greedy of immediate lucre than anxious to ensure the future of their production, have neither sought a rational method of collection nor of improved culture, the only methods capable of increasing or maintaining the original annual production. Felling mercilessly the producing trees, and only extracting the guttiferous latex but very imperfectly, they make a gap round about them to such an extent, that if we look at the prices paid in the beginning and those now paid for even inferior goods, we are really frightened at the constant progressive rise in the price of gutta percha. But not to anticipate; we shall have occasion to return to this subject, so full of interest, and examine what has been done and what remains to be done to cope with the danger of an eventual dearth of gutta percha. The elucidation of the reasons why governments, scientists, and manufacturers attach so much importance to this question will, moreover, be facilitated by the study of the botanical sources and the chemical and physical properties of this substance. But let us state at the outset that this study bristles with difficulties. We get swamped in a labyrinth where others, more competent than we, have gone helplessly astray, and we have only one object: to profit by their experience and their weary efforts to be able finally to throw some light

TABLE LXXXVII.—OBACH'S ANALYSIS OF HISTORICAL SAMPLES OF THE COAGULATED LATEX OF *ISONANDRA GUTTA* (HOOKER).

No.	After Drying in Vacuo.					Gutta Percha Proper.	
	Percentage Composition.			Total.	Ratio.	Percentage Composition.	
	Gutta.	Resin.	Dirt.	G. P. (G. + R.).	Gutta. / Resin.	Gutta.	Resin.
1 . .	70·4	17·6	3·0	97·0	4·5	81·8	18·2
2 . .	74.5	14·2	4·3	95·7	3·0	74·6	25·4
3 . .	75·6	18·3	16·1	83·9	0·1	90·1	9·9

1. Piece of riding whip sent by Lobb from Johor, and so described on slip of paper found with another of Lobb's samples to Kew Herbarium in 1846, and described by Sir W. Hooker as wood (*London Journal Bot.*, 1847, vol. vi. p. 33). Very light, hard, fibrous, showing ebony black lines; yielded very light strong gutta and light yellow soft resin. A sample from Johor, collected about 1890, contained 90 per cent. of gutta proper with only 8 per cent. resin quality.
2. Cover of tin box in which flowering branch of *Isonandra gutta* was sent toSir W. Hooker (*Lond. Journal Bot.*, 1847, vol. vi. p. 464). Dark brown, hard, containing dirt and small pieces of bark; yielded light brown strong gutta and light yellow soft resin.
3. Coagulated latex of offspring of same tree as Lobb's botanical specimen, collected by Serrulaz in 1847. Light brown, hard, contained 5 per cent. water; yielded light brown not very strong gutta, and light yellow soft resin (*Lum. Electr.*, 1890, vol. 38, p. 411).

where it would appear pleasure had been taken in increasing the darkness. Dr. Beauvisage, in a brilliant inaugural thesis, "Contributions to the Study of Gutta Percha," delivered in Paris on the 14th February 1881, took as his motto these verses of Lafontaine—

"D'abord il s'y prit mal, puis un peu mieux, puis bien,
Puis enfin il n'y manqua rien."[1] (Livre XII. f. ix.)

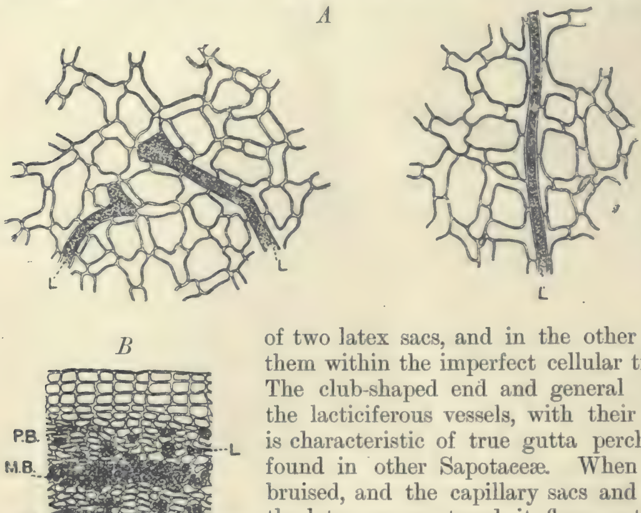
We do not hope that in our book *il ne manquera rien* (nothing will be deficient); but we have the firm conviction that—with the help of the numerous researches of our predecessors, and as far as the actual state of the knowledge that has been acquired will allow—we also will contribute to make the sphinx speak, of which Leon Brasse recently said, "the more he studied gutta percha from a practical point of view, the more obscurities he found in it" (*Lumière Electrique*, October 1892, vol. 46, pp. 51, 109, 160).

[1] "First he set about it badly, then a little better, then well;
Then at last he was quite proficient at it."

CHAPTER I

DEFINITION OF GUTTA PERCHA—BOTANICAL ORIGIN—HABITAT

THE gutta percha latex is contained in isolated receptacles or sacs mainly in the inner parts of the bark. It is also present in the leaves. Fig. 105 *B* shows a section through a small branch, and (Fig. 105 *A*) through a leaf. Numerous latex receptacles, *L*, in the primary and secondary bark, *B.P.* and *S.B.* of the branch, as well as in the pith, *P*. The sections through the leaf show in one case the termination of two latex sacs, and in the other the course of one of them within the imperfect cellular tissue or merenchyma. The club-shaped end and general bone-shaped form of the lacticiferous vessels, with their segmentary division, is characteristic of true gutta percha plants, and is not found in other Sapotaceæ. When the bark is cut or bruised, and the capillary sacs and tubes which contain the latex are ruptured, it flows out with greater or less abundance according to the species of the tree. This milk possibly serves in the plant economy as a protection; still it is primarily an excretion, since it is discarded by the tree in its dead leaves and bark, and the bark of the live tree can be tapped and the latex removed with no apparent injury to the tree.



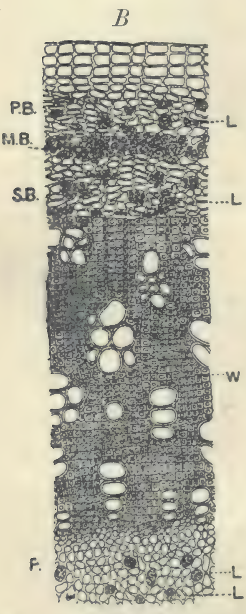


FIG. 105.—Microscopic section through *A*, leaf of *Palaquium gutta*; *B*, branch.

A chemical examination of the milk or latex coming from the gutta percha trees upon wounding the bark, shows it to be composed of an emulsion of water and oil in a finely divided state. According to the species of tree, the water varies from a small (best species) to a very large percentage (poor species). A drop of the milk caught on the finger undergoes no apparent change for a few minutes, but by the end of this time a thin rubbery scum can be observed to have formed on the surface. If this be removed, a second film will form, and so on until the entire drop has become a small piece of a tough, leathery substance. When a fresh drop is worked between the fingers the hardening process or coagulation takes place very quickly, and by boiling or adding certain chemicals, such as mineral or vegetable acids, alum, salt, etc., it takes place almost instantaneously. What the nature of this hardening process

is appears to be unknown. The subject is being investigated in the Philippines laboratory. After coagulation sets in, the oily portion becomes hard and tough, while most of the water separates or is enclosed mechanically (Sherman).

Gutta percha as it comes to European markets is usually in the form of large blocks of various shapes—cylindrical rolls, square cakes, flat bottles, etc.—which are characteristic to a certain extent of the district whence they come. Sometimes the native collector shows artistic tendencies, and moulds the gutta percha into the shape of birds, alligators, etc.

Differentiation between indiarubber and gutta percha; similar origin of both.—At first sight *gutta percha* (*gummicum plasticum*)—which should be written *gueutta pertcha*, to give it its true pronunciation—is a vegetable product analogous to rubber, as much by its method of formation in nature as by its composition. Like rubber, it originates in the milky juice of certain trees, and again, like rubber, it would appear to consist essentially of a hydrocarbide, in which its two elements, carbon and hydrogen, are present in somewhat similar proportions.

A wide difference between their properties.—But there the likeness stops; and it is difficult to understand how two substances, so dissimilar in properties, were coupled together, at random as it were. These properties, so very different, were admirably described by Morellet in his inaugural thesis previously quoted.

Different action of mechanical force on the two bodies.—"Rubber," says Morellet, "is essentially an elastic body, *i.e.* but little capable, in its natural state, of preserving in a permanent manner the change in shape which a mechanical force acting upon it causes it to undergo; whereas gutta percha can preserve those changes of shape produced on it by the action of forces of the same nature."

Comparative action of heat on indiarubber and gutta percha.—"Natural rubber, that is, rubber which has not been treated with sulphur, indeed softens and becomes more malleable under the action of heat, but it preserves its elasticity if the heat does not exceed certain limits, beyond which it loses its properties, and consequently is profoundly altered, not only in its physical properties, but in its chemical properties as well. But under the action of a heat so regulated that it does not exceed 100° C. (212° F.), in boiling water, for example, gutta percha becomes a highly plastic and malleable substance, capable of preserving, on cooling, the appearance and shapes given to it at that temperature."

Their essential differences embodied in the Latin names of the two substances.—These two principal characteristics are distinctly brought out in the Latin terms by which science has designated the two different substances, in giving to rubber the name of *gummicum elasticum*, and to gutta percha the name of *gummicum plasticum*.

Comparative action of air, light, and moisture on the two bodies.—Rubber, under the simultaneous action of the air, of a regulated temperature, and time, gradually loses its properties, and becomes converted into a tacky, viscous, more or less fluid substance. Gutta percha, under similar conditions, behaves quite differently, and changes into a brittle, resinous body. These transformations are more or less long in manifesting themselves, according to the different varieties and the conditions of the experiment. Water and a low temperature retard these changes of state in the two products. It is perhaps in these properties that the greatest difference exists between the two substances which are being differentiated from one another.

Comparative action of sulphur on rubber and gutta percha.—Another distinction of capital importance is that exhibited when these two substances are treated with sulphur. It is easy to combine rubber with sulphur so as to obtain a homogeneous elastic substance, preserving at different temperatures below 150° C. (302° F.) the same properties as at the ordinary temperature; whilst if it be attempted to combine gutta percha directly with sulphur the operation is unsuccessful, in spite of every precaution which may be taken; and if it be tried to combine an intimate mixture of rubber and gutta percha with sulphur, more

or less negative results are obtained, just as gutta percha enters into the mixture in greater or less proportion. When gutta percha enters into the rubber mixture to a greater extent than 10 per cent. the operation fails, and, on vulcanisation, there is only obtained a product showing on the surface, and also when cut, numerous blowholes and vesicular cavities. In the trade the mixture is said to puncture on vulcanisation.

Difference in dielectric properties. — The dielectric properties of the two substances are far from being identical, and that, moreover, is one reason why it is not desirable to confuse *gum elastic* with *gum plastic*. The above are the most striking characteristics which differentiate essentially between the two products. They are, moreover, further explained, as by the essentially different botanical origin of the plants from which they are produced, as well as by the nature of the latex secreted. But before proceeding further it is necessary to define well the value of the term gutta percha. Here, again, we are in presence, not of different properties, but of data furnished by men of science, explorers, and manufacturers, which have nothing in common with similar information on the botanical origin of rubber. Whilst every one is agreed in acknowledging that it is the *Heveas* which yield *Para* rubber, *i.e.* the prototype of the species, all is obscurity and contradiction when it is a question of establishing the botanical origin of commercial gutta percha, and it would seem that a malignant pleasure had been taken in obscuring the question rather than in bringing some perspicuity and method to bear upon it.

Manufacturers, merchants, travellers, scientific men, and even governments, tried to find sources of gutta percha in other regions of the intertropical zone, in other trees, whether belonging to the *Sapotaceæ* or not, and which had not been previously examined from this point of view. "This period of research is still going on. The results, collected by science in different parts of the world, are very numerous, but very imperfect, and have not, as yet, given the desired practical results. Scientific men discovered, in the Indian Archipelago, Indo-China, Hindostan, tropical Africa, the Guianas, Brazil, etc., trees the juice of which may yield a good, a mediocre, or a bad gutta percha. They determined, with greater or less care and exactitude, the physical and chemical properties of these different products, but their investigations ended there, whilst manufacturers continued to receive most diverse substances, through numerous savage or civilised merchants, who could not or *would not* (for a very good reason if we consider the point well) give exact indications upon the botanical origin, nor even upon the exact geographical origin of these products. The diversity of these is such that it would appear impossible to determine the properties by which one could recognise the substance designated under such and such a commercial name. Any attempt to scale the commercial price current is absolutely vain; to clear up this question, another road must be followed, and we must try to recognise, at the place of arrival, products whose origin and properties could be better studied at their point of departure. *That is what I attempted to do, but in which I have in no way succeeded.* The success of such a tentative does not appear impossible to realise, but it would require long years of profound research, and collaboration of a great number of enlightened but *disinterested* persons." That which was an almost insurmountable difficulty for Dr. Beauvisage in 1881 is a little less so to-day, thanks to the labours not only of Beauvisage himself and his predecessors, from the days of Montgomerie, *i.e.* Lobb, Bentham, Hooker, Oxley, Wight, de Vriese, Burck, Pierre, Seligmann Lui, Brau de St. Pol Lias, and Serrulaz, but also and more especially to the labours and discoveries of Heckel, Schlagdenhaufen, Jungfleisch, and of L. Brasse, Obach, etc. L. Brasse, in *La Lumière Electrique* (see Bibliography), imparted at last some order to the classification of commercial gutta perchas, and thus enabled us to get at the real origin of the producing plants.

Leon Brasse's researches.—Leon Brasse, whom a long experience of practical manufacture initiated into the real wants of the industry, seems to have best grasped the only way of looking at the question, and his work may be resumed in that

characteristic phrase which brings out all its practical value: "*The question has always been badly postulated: there is not a good kind of gutta percha but several good kinds, each of which responds to a certain use, and it is these species which should be propagated.*" By so postulating the question, Leon Brasse not only pointed out the real road which should be taken to elucidate so important and still so obscure a subject, but he also supplied us with precious documents, the best of their kind known up to now, and we do not hesitate to appropriate them, but not without rendering homage to the science and to the talent of the writer. But he has made use of and been aided by the researches of the men of science previously quoted. He has been able to co-ordinate them in such a manner that to attempt to do better would be difficult in the present state of our knowledge.[1] At the commencement of the manufacture of submarine cables, trees were abundant, only good qualities were used, only large trees were exploited, and those which yielded an inferior product not at all. "But, as we can satisfy ourselves by examining the products preserved in collections, different qualities of gutta percha were even then used in admixture. What proves it is that the tools used at this epoch for the cleansing of the gum resin—tools still in use at the present day in some manufactories—could not have purified Isonandra gutta, if it had not been previously mixed with more plastic varieties. Later on, owing to the good qualities becoming rare, more and more inferior kinds were introduced into the mixture, and, to obtain the good qualities which were used in less proportion, but which it was necessary to use as far as possible, recourse had then to be made to barely adult trees. The production of prime quality gutta percha had thus become reduced to such a minimum, and its price so high, that at the Electrical Congress of 1881 the necessity was recognised of applying a system of rational culture to the gutta percha plants. Hence the mission of Seligmann Lui, who visited the east coast of Sumatra and the western coast of the Malay Peninsula. Early in 1883, Wray explored the State of Perak on its western coast, and Burck studied all the guttifers of Sumatra. Since then Serrulaz attempted, in several voyages, to finish the work of Seligmann Lui, and in 1871 [2] he refound the *Isonandra Hooker* in the same ravine of Boukett-Timah where Lobb first discovered it in 1847. These expeditions revolved in the same circle. They, however, agreed passably between each other. Seligmann and Burck give the preference to the *Dichopsis oblongifolium*. Wray, who explored Perak, reports in it the *Dichopsis pustulatum* (Pierre),[3] and Serrulaz, who remained in the environs of Singapore, refound the *Dichopsis gutta* or *Isonandra gutta*. It is to be regretted that these explorations were all conducted on the rivers of the Strait of Malacca, because the gutta percha produced by this region is not the best of that which we use; and, besides, the *yield in gutta percha of an Isonandra is asbolutely miserable. There ought to be three other gutta percha-producing plants, giving a better and more abundant gutta, and that is what Leon Brasse proposed to examine.* If, in the future, the juice of the *Dichopsis* or *Palaquium gutta, oblongifolium* or *pustulatum*, should be alone available for industrial purposes, it would be necessary to modify the methods of manufacture, and the result might be quite different from that expected. Whilst, with a continuous supply of the kinds used in the beginning, before the dearth forced very inferior species of gutta percha to be used, future submarine cables will last equally long as those which have given such good results." Byzantine discussions as to whether the word *gutta percha* is indeed the appellation which should be given to the substance, or if *gutta taban* or *tuban* should be substituted for it, need not find a place here. Custom, rightly or wrongly, has adopted the name *gutta percha* to designate

[1] Obach (*Cantor Lectures*) has since thrown more light on the problem. The translator has condensed and embodied some of his Tables.—Tr.

[2] See translator's Preface. The correct date on the face of it is 1887.—Tr.

[3] Wray's samples, analyses of which are given on p. 318, are in custody of Kew authorities and Institute of Electrical Engineers. He started on his expedition early in 1883. Burck, who started towards end of that year, discovered fourteen species of gutta percha yielding trees.

commercial *gum plastic.* We shall therefore definitely adopt that term; and it only now remains to find out, at the proper time, if there be not several varieties of the species, and if it be not desirable to give to the chemically pure substance another designation by which it may be distinguished from the raw product from which it is extracted. As to the true meaning of the term *gutta percha* or *pertcha,* according to Serrulaz, the word *gutta* (*guetah* or *gueutta* in the Malay language) is only used in an absolutely general sense, and means gum, and the word *gommegutte* (gamboge) according to him is a pleonasm. The word *Pertcha* or *Perfia,* which the French alone pronounce *percha,* in no wise signifies, as all explorers assert, Sumatra. Sumatra, in Malay, is termed *Perna,* that is to say, the world, the terrestrial portion inhabited; whilst *Pertcha* signifies rag, strip of cloth (*English,* scraps), and designates very exactly the appearance of gums which before treatment with hot water present the appearance of rags reduced to paste and compressed. It would not, therefore, be astonishing if this designation, which does not belong to common Malay, had been employed, not by the native working in the forest, but much rather by the merchant belonging to a higher class in those countries. This opinion may be taken as true, or at least the most probable, and the matter allowed to drop.[1]

The botanography and habitat of gutta percha trees.—The botanical origin of gutta percha as well as the questions which relate to the habitat of guttiferous plants must now be dealt with. As soon as the valuable properties of gutta percha had been recognised in Europe, and a demand had been created for the article, the countries all around Singapore were searched with great avidity for Taban trees, and almost a craze for getah-collecting sprang up amongst the indigenous population. The consequence was that an immense number of trees of great size and age, probably hundreds of thousands, were ruthlessly destroyed during the first four or five years, and whole forests denuded of them, like those of Singapore. The exploration was conducted with such assiduity, that before the year 1848 came to a close, the much coveted Taban tree had already been discovered in Pahang, Johore, Malacca, Selangor, Perak, and Penang on the Malay Peninsula, besides the islands of Rhio, Gallang, and Singga in the Johor Archipelago. It had also been met with in Siak, Kampar, Indragiri, Tongkal, Jambi, and Palembang, on Sumatra, and in Coti, Passir, Pontianak, Sarawak, and Brunei on Borneo. Since that time the tree has been found in the northern and north-eastern parts of Borneo, on the west coast of Sumatra, and in some other districts on the east and west coasts of the Malay Peninsula. But if the flora of temperate climates contains a certain number of rubber-producing plants, in relatively feeble quantities it is true, and if the tropical and intertropical zones, bounded by the thirtieth degrees of north and south latitude, are the chief rubber-producing districts, it is not so with gutta percha. Only an extremely limited zone—represented by that belt of land situated between the third degree of south and fifth degree of north latitude—is adapted for guttiferous vegetation. Moreover, every one knows that the Asiatic continent is separated from the geological Oceanian continent by a deep submarine fault of at least 200 metres (656 feet), stretching along the Islands of Sumatra and Java, to enter by the Strait of Bali into the Java Sea; there it distinctly separates the Celebes (Australian continent) from the Borneo group (Asiatic continent), goes round about Borneo to divide into two ramifications, one towards the Soulon Isles and the other towards the Gilolo Islands. The fauna as well as the flora on each side of this fault are perfectly distinct. On the Australian side neither arengani palms, teak-wood, ferns, orchids, nor the mosses of the Java flora are to be found. There are no more tigers nor other felines, and the greater number of the birds which live in the woods of Borneo, Java, and Sumatra are unknown. It is the same in regard to the plants, which readily yield real gutta percha.

The real gutta percha country forms only a very limited extent of land, and belongs exclusively to the Asiatic continent, and is situated between the 102° and

[1] *Tschirsch Die Harze,* etc., p. 894, 1906, says *Percha* is an old name for Sumatra.

112° of French longitude. The French meridian passes through Paris. According to Obach, the gutta percha region extends 6° on either side of the equator, and from 99° to 119° longitude east of Greenwich. Total area, 1,140,000 square miles. Of terrestrial area = 285,000 square miles (40 per cent.)—only but small portion locally suitable for growth of gutta percha trees. The Asiatic part is the productive region of gutta percha in the proper sense of the word.

That is not to say that other countries situated near to the equator, and bounded on the north as well as on the south by the above-mentioned latitudes, are incapable of furnishing, if not gutta percha properly so called, at least analogous resins. Quite the contrary; and we shall see in the sequel that it is precisely in those parts of the globe, and in those parts only, that the sagacity of the searcher should be exercised, so as to remedy the ever-increasing gutta percha dearth of Malasia and Papua.

Nowhere else on the globe, outside the area of the Malay Archipelago, have any *genuine* gutta percha trees been found, and this is the more remarkable as the *Sapotaceæ* to which they belong are distributed all over the tropics, and are also of great antiquity, having even representatives amongst the fossil plants. It might, perhaps, be asked whether gutta trees have not been found in the islands adjacent to those confined by the boundary line on the map; for instance, in the large group to the north of Borneo, the Philippines, or the islands Celebes and Java, to mention only the more important ones. The answer is, that hitherto no *genuine* gutta percha trees have been discovered there. *Getah* trees, in the Malayan sense of the word, exist, no doubt, but none of the right description.[1]

Sapotaceæ or Sapotads.—However that may be, as it is the family of *Sapotaceæ* which yields the greater portion of guttiferous plants, it will be useful to give, according to Baillon, a very summary botanical description of this family of the *gamopetalous sapotaceous dicotyledons.* Of gamopetalous dicotyledons, with regular flowers and convex receptacles: The corolla is generally imbricated, and bears four or five fertile stamens, placed above its divisions. Moreover, alternate staminodes are often observed. The latter may be awanting; and sometimes also the number of stamens exceeds those of the lobes of the perianth. The superior ovary is hollowed by 1 to 5 cells, rarely more, placed above the sepals, and each containing an ascending ovule, with an exterior and inferior micropyle. The fruit is a berry, and the grains have often a long and wide hilum, which occupies a large portion of their internal edge, cutting moreover into the surface of the seed, which is smooth and polished. The ascendant seed is albuminous or exalbuminous. Trees or shrubs of tropical regions, generally rich in milky juice, which often forms gutta percha. Leaves generally alternate, with or without stipules. Flowers solitary or in cymes, often implanted in the wood of the stems. This family is often divided into the *Bassiæ* (*Illipæ*), *Lucumæ*, *Mimusopæ*, *Bumeliæ*, and *Chrysophylæ*. [This latter group should perhaps disappear (Pierre).] Amongst the numerous tribes of *Sapotaceæ* it is evidently those belonging to the genus *Dichopsis* (or *Palaquium* or *Isonandra*) which yields the greatest number and the best varieties of guttiferous trees. The only really important ones would appear to be—1. The *Dichopsis gutta* (Th. Lobb, Benth. et Hook.), or *Palaquium gutta* (Burck), or *Isonandra gutta* (Serrulaz). 2. The *Dichopsis oblongifolium* (Beauvisage, Burck), or *Palaquium oblongifolium* or *Isonandra oblongifolia* (Brau de St. Pol Lias, Teysmann). 3. The *Dichopsis* or *Palaquium Borneense* of Teysmann, the *Dichopsis* or *Palaquium Treubii* and its variety *parvifolium* (Burck). 4. After the genus *Dichopsis* or *Palaquium* come the genus *Payena*, that of the *Mimusops*, and finally that of the *Bassia*.

1. *Dichopsis gutta*—(*Botanical details according to Burck*).—*Folia petiolata obovato-oblonga breviter acuminata, nervis secundariis in folii substantiam immersis* 20–30 *utrinque: Arbor elata, ramuli juniores rubiginoso-pubescentes. Folia modice*

[1] Sherman, *loc. cit.*, says the area of the other [than Palaquium gutta] or inferior species is extended eastward so as to take in the Philippines, Celebes, Java, and the northern half of the Malay Peninsula.

petiolata, sub-coriacea, obovata-oblonga, supra viridia subtus aureo-nitentia, breviter acuminata 11 *centim. longa, supra medio* 4/2 *centim. lata, basi in petiolum gracilem* 1·5–2·5 *centim. longum attenuata, nervis lateralibus arcuatis, parallelis subhorizontali-patentibus* 20–30 *utrinque in folii substantiam immersis via conspicuis. Alabastrum ellipsoïdeum. Flores axillares, sæpius in axillis foliorum delapsorum fasciculati. Fasciculi* 2–6 *flori. Flores* 2 *millim. longi, pedunculati. Pedunculi* 3 *millim. Calyx ellipsoïdeo-campanulatus, laciniis ovatis, aureo-nitidis, exterioribus coriaceis subvalvatis, interioribus tenuioribus. Corolla subrotata: tubo calicem vix superante, laciniis tubo æquilongis lanceolo-ovatis v. elipticis, obtusis, patentibus. Stamina* 12 *biserialia. Filamenta æqualia filiformia laciniis corollæ æquilonga. Antheræ ovatæ, glabræ, acutæ. Ovarium subglobosum, pubescens. Stylus filiformis staminibus longior. Stigma obtusum. Bacca carnosa, ovoidea calycis laciniis suffulta fusco-tomentosa,* 3·5 *centim. longa,* 2·5–3 *centim. lata, pluribus loculis abortientibus obsoletis. Semina* 1, 2, *v.* 3, *ellipsoïdea vel a latere compressa testa crustacea nitida, hilo magno, seminis superficiei majorem partem obtegente.*

FIG. 106.—Branch of *Dichopsis gutta* (*Palaquiun gutta, Isonandra gutta*).

Burck gives the above description, as this species up to then had not been exactly and completely described, no botanist having seen either the fruit or the seeds; and because the *Dichopsis gutta* is a plant which yields an excellent product, and which, in virtue thereof, should be cultivated by the Netherlands Government. To these details it will be useful to add those given by Obach, Professor Baillon or Dr. Beauvisage.

Obach describes the *Dichopsis gutta* as follows:—"It is a lofty tree with a perfectly straight cylindrical trunk, and has, when fully grown, a height of from 60 to 80 feet, and a diameter of 2 to 3 feet; but it appears that in some localities, Perak, for instance, trees considerably over 150 feet high, and 4 to 5 feet in diameter, have been met with. The leaves are crowded together at the ends of the branches and

are placed alternately; their form is obovate-lanceolate, and they have a small projection or beak at the apex. Leaves from old trees measure about 4 to 5 inches in length, and $1\frac{3}{4}$ to $2\frac{1}{2}$ inches in width at the middle; whereas those from young trees are much larger, reaching a length of 9 inches and a breadth of nearly 3 inches. I purposely mention this in order to show that variations in the shape and size of the leaves are not alone sufficient to indicate a difference of species, as has sometimes been supposed. The upper surface of the leaves is bright green and the underside golden brown, when the trees are young, and reddish brown when old, this colour being due to the presence of a dense layer of silky hairs, which also cover the mid-rib and the petiole; the latter is usually about an inch or a little more in length. The secondary veins branch out laterally from the mid-rib, nearly at right angles, and are not very conspicuous, being sunk in the substance of the leaf. They number 20 or 30 on each side, which is of some importance to know, as we shall see. The flowers, of which there are four, grouped together in the axil of the leaves, are white, the calyx being of a golden brown colour; there are twelve stamens in single series, inserted into the throat of the corolla with sagittate anthers, turned outwards. The ovary is superior and six-celled, terminating in a single style, which is much longer than the stamens. The fruit is a fleshy egg-shaped berry about $1\frac{1}{2}$ inches long and 1 inch in diameter."

Further botanical details of Dichopsis gutta (*Baillon*, *Beauvisage*).—The group of young, unexpanded flowers comprises six flowers in a dichotomous cyme, in the middle of which is a cicatrice, apparently left by the fall of the flower of the first generation. This inflorescence is accompanied by decussate bracts. The gamosepalous *calyx* consists of three external, coriaceous subvalvular divisions, and of three thinner, internal, imbricated divisions, alternating with the former. The *corolla* consists of six twisted divisions, alternating with the sepals, so deep that the corolla is hardly gamopetalous. The *andrœcium* comprises twelve stamens, all apparently fertile, so far as can be judged in so young a flower. In spite of their small dimensions, two different sizes may be recognised. The six larger are opposite the divisions of the corolla; the six smaller are alternate with the former, and with the divisions of the corolla. The anthers are extrorse. The *ovary* is six-celled, each containing an ascending ovule, incompletely anatropous, with the micropyle inferior and exterior. The style is cruciform, truncate, then conical at the apex. The young fruit is ovoid, conical. Around it are the six persistent sepals. The young elongated seed, acute at the top, is furnished with a coriaceous envelope, in the interior of which there would appear to be a viscous albumen. *Serrulaz's botanical description of Isonandra gutta.*—Serrulaz (*Academie des Sciences*, 1890, pp. 433–426), gives some complementary details of this plant (the prototype of the gutta percha tree). In chronological order it is the first plant mentioned as a producer of gum plastic, of so great dielectrical power, and it would appear to have played the same rôle in the history of gutta percha that the *Hevea Guyanensis* has done in that of indiarubber. Both of them known and mentioned from the outset, the one as yielding gum elastic and the other as gum plastic *par excellence*, at the present day, being rare, they are neglected; the one being replaced in industrial exploitation by *Hevea Braziliensis*, the other by *Dichopsis oblongifolium.* "The *Isonandra gutta*, at the age of thirty years, *i.e.* when full grown, has a trunk of 13 to 14 metres (43 to 46 feet) up to the origin of the lowest branches, and a very regular circumference of 0·9 metre (say 3 feet) at 2 metres (say $6\frac{1}{2}$ feet) above the ground. This trunk is, moreover, almost cylindrical. The leaves of the young tree are often as much as 22 to 23 cm. in length by 7 cm. wide in the middle, whilst in the full-grown tree they are only 11 to 12 cm. in length by 4 to 5 to 6 cm. The shape and size of the leaf in the *Dichopsis* vary so much with the age of the plant in consideration that there is nothing astonishing in the great number of species introduced into botany from the examination of the branches, destitute of floral elements, and not comparable between themselves. The petiole has a length varying between 1·75 and 3·75 cm. The flowers are from 13 to 14 mm., and the peduncle 4 to 6 to 7 mm.

The fruit presents, in the two perpendicular directions, the average dimensions of 3 to 3·5 cm. by 2·5 to 5 cm., and sometimes 4 by 3 to 3·5 cm. The seed is generally 1·8 to 2 cm." In the Malay forests traversed by Serrulaz, during four years he only found five trees capable of being confounded at first sight by their foliage, and in reality by the latex, with the *Isonandra gutta.* There can be no possible confusion with the other *Dichopsis,* which are likewise differentiated from it, having regard to the quality of their gutta, by the *Payena Lerii* (*Gutta Sandeck*). Serrulaz considers gutta sandeck as a complex mixture, but he only studied the *Isonandra gutta*; he thinks it the plant *par excellence* which furnishes the raw material for the manufacture of submarine cables, and he regards the *Bassia Parkii* and *Mimusops balata* guttas as only giving negative results. He regards the *Payena Lerii* as only of service in yielding an apt adulterating agent. The only guttas which, according to Serrulaz, can be used as dielectrics in the core of cables are secreted by trees of the genus Isonandra, with an exclusive habitat in Malasia. In his communication to the *Academy of Sciences,* of date 15th September 1890 (pp. 423–436), Serrulaz says: "The clearing or deforesting of the interesting zone of Malay forests is going on at a rapid rate; the native, by cutting all the barely ripe trees he encountered, and by acting similarly with their shoots—that is, by hindering them from reaching the adult stage—has, so to speak, for forty years suppressed their reproduction and multiplication. The gutta perchas that were used at the outset of the industry are now only found exceptionally; those which have replaced them will have the same doom in about fifteen years. Exportation is beginning to cease from place to place in the Malay ports. The insufficient plantations undertaken in the Dutch Indies have produced, above all things, not the best species, but those whose latex is most abundant, that is to say, the least valuable kinds. Submarine telegraphy is on the eve of seeing itself deprived of an article that is indispensable to it in the present state of the science, and the origin of this gutta remains badly known. In chronological order, the first plant mentioned as a producer was the *Isonandra gutta* (Hooker). This tree, the only one of which the coagulated latex was sent to Europe at the same time as the commercial samples, and which had been passed as satisfactory by practical men, has remained incompletely described. It is described as a species extinct since 1857 in the Island of Singapore, which no longer exists in the Malay forests. In reality this species has become very rare, but it still subsists. Adult representatives still multiply (in 1887) on Chasseriau estate, in the ravines of Boukett-Timah (tin hills), situated in the centre of Singapore, where it was discovered in 1847 by Thomas Lobb. When I refound it in 1887, all exploitation had for a long time (thirty years) ceased, and the extinction of its species was regarded as an accomplished fact. Yet, barely three years ago, in the last scraps of the ancient forests of this island, trees of this nature, then already full grown, still existed, represented more especially by shoots. There only existed there but one variety of a single species of gutta percha tree, which agreed with the specimens figured in Plate XVII. of the *London Journal of Botany,* vol. vi., given by Hooker of his *Isonandra gutta.*" (See p. 284 and translator's Preface.)

2. *Dichopsis oblongifolium—Botanical details according to Burck).—Folia petiolata v. lanceolato-oblonga longe acuminata, nervis lateralibus* 20–30 *utrinque in folii substantiam immersis* (*Isonandra gutta var. oblongifolia de Vriese, Isonandra gutta var. B. Sumatrana miq. Dichopsis nov. sp. Beauvisage*). *Arbor elata; ramuli juniores rubiginoso-pubescentes. Folia modice petiolata oblonga v. lanceolato-oblonga subcoriacea, supra viridia subtus aureo-nitentia, longe acuminata; folia juniora, reliquis majora usque ad* 22 *centim. longa,* 7·5 *centim. lata, basi in petiolem gracilem* 1·5–2·5 *centim. longum attenuata nervis lateralibus arcuatis parallelis horizontali patentibus* 20–30 *utrinque in folii substantiam immersis vis conspicuis. Alabastrum oviodeum. Flores axillares: sœpius in axillis foliorum delapsorum fasciculati. Fasciculi* 1–6 *flori. Flores* 10 *millim. longi pedunculati.*

Pedunculi 1·5–2 *millim.: Calyx ovideo-campanulatus, laciniis obtusis, ovatis aureo-nitidis, interioribus tenuioribus. Corollæ tubus calycem superans, laciniæ lanceolatæ obtusæ patentes tubo sub æquilongæ. Stamina* 12 *biserialia. Filamenta æqualia filiformia laciniis corollæ æquilonga. Antheræ glabræ ovatæ acutæ. Ovarium subglobosum pubescens. Stylus filiformis staminibus longior stigma obtusum. Bacca carnosa, ovoïdea rudimento styli coronata, calycis lacinniis suffulta, fusco-tomentosa* 3·5–4 *centim. longa,* 3–3·5 *centim. lata, pluribus loculis abortientibus obsoletis. Semina* 1, 2, *v.* 3, *ellipsoïdea v. a latere compressa testa crustacea, nitida, hilo magno seminis majorem partem superficiei obtegente.*

Fig. 107.—*Dichopsis oblongifolium.*

Discovered in Sumatra by Teysmann and Burck.
" Borneo by Teysmann and Tromp.
" Rhio Archipelago by Teysmann.
" Malacca by Brau de St. Pol Lias.

On the eastern coast of Sumatra by Seligmann Lui (under the name of Mayang Derrian). The *Dichopsis oblongifolium* is the Taban Sutra of Perak. It is very closely allied to the Taban Merah, and its discoverer, de Vriese, considered it merely a variety of Hooker's *Isonandra gutta.* However, it is now understood to be an independent species. It is a tree of smaller size, with leaves of a more decided brown on surface. The flowers have a reddish tinge, and the general appearance of the bark is said to be quite different. This tree yields the best product of all gutta percha trees in the upper regions of Padang, and this gutta percha is the best of all the sorts encountered by explorers (Brasse). This is the opinion of both Seligmann Lui, who found it on the eastern watershed of Sumatra, and of

Brau de St. Pol Lias, who reports it from Perak (Malacca). It is also found in Borneo (Pontianak, Banjermassin). The hamlet of Bloran (district of Djambon, Sumatra) possessed in 1884 seventy-seven of these trees, the remainder of 400 feet planted on the 28th August 1856. These plants were brought to the number of 2000 from the western coast of Borneo on the 3rd March 1856, and distributed amongst the different residents. It is not known what has become of the others. A plantation of trees of this species was tried in Borneo. It did not succeed. It is on the mountains of no great height or on the smaller hills beyond reach of the floods that the finest trees are found. The less the situation is exposed to stagnant water, the better they grow. This plant is so sensible to the influence of a good situation that a choice of bad ground—as in the Borneo plantatations under colonial inspection, and entrusted to individuals—is enough to kill it. The gutta yielded by the *Dichopsis oblongifolium*, *getah* Taban Sutra, is of excellent homogeneity and durability. Freed from bark and woody particles, it becomes

FIG. 108.—*Dichopsis Borneense* (after Burck).

very tenacious and elastic, and may be easily bent without breaking. Immersed in hot water, it may be moulded and caused to assume any shape without becoming tacky, and on cooling resumes its ordinary solidity. The colour varies from red to deep brown. As in all kinds of gutta percha, the juice is a milky white when it flows, and remains so if it be preserved without mixture. The brown colour is due to admixture with cortical and ligneous particles which, during heating, communicate their colouring principle to the thickened juice. The *Dichopsis Borneese*, the *Dichopsis Treubii*, the *Parvifolium*, and the *Palaquium Vrieseanum* would appear to be botanical varieties without influence on the quality of the gutta. The *Dichopsis calophylla* (Benth. et Hook.) would appear to be the *Mayang Batou* of Seligmann Lui, which yields a brighter and redder gutta than the *Dichopsis oblongifolium*, with not so fine a fibre, and perhaps also not so rigid. It is described by Burck as follows:—

3. *Dichopsis calophylla.—Folia petiolata, obovato-oblonga breviter et obtuse acuminata, nervis lateralibus* 10–12 *prominentibus. Petiolus* 1–15 *centim.* (*seu*

Isonandra calophylla T. et B. Isonandra chrysonopta et costata de Vriese, Njata-dyangkar. in Hort. Bot. Bogor. Palaquium calophyllum Pierre). *Arbor alta ramulis junioribus aureo-tomentosis. Folia petiolata, coriacea, obovato-oblonga supra viridia subtus aureo-sericea breviter et obtuse acuminata* 10–15 *centim. longum decurrentia, nervis costalibus* 10–12 *utrinque patulis subtus prominentibus. Flores axillares fasciculati. Pedunculi* 20–25 *millim. longi, graciles reflexi. Calyx ovoïdeo-campanulatus laciniis ovatis obtusis. Corolla subrotata tubo calyce æquilongo, laciniis ovatis, acutis, patentibus tubo longioribus. Stamina* 12, *filamenta æqualia, filiformia, glabra corollæ laciniis æquilonga. Antheræ ovatæ, obtuse acuminatæ. Ovarium globosum aureo-pubescens. Stylus filiformis staminibus longior. Stigma obtusum. Bacca carnosa, depresso-globosa, calycis persistentis laciniis suffulta, aureo-tomentosa* 2½ *centim. lata*, 2 *centim. longa, longe pedunculata. Semen unicum subglobosum, tuta crustacea nitida, hilo magno.*

FIG. 109.—*Dichopsis Treubii* (after Burck).

The *Dichopsis selendit*, or *Mayang Korrik* of Seligmann Lui, which the native Malays, according to Burck, call *Njatoeh selendit*, and the native of Sumatra *Halaban*, yields a very hard gutta, unfit for cable manufacture, but perfectly fit for being used in the industrial mixings to be dealt with later on. The *majang Djerinjin* and the *majang Kartas* of Seligmann Lui belong to an almost identical variety; the gum resins which proceed from them have the qualities and defects of the *Dichopsis selendit*. The *Dichopsis Krantziana* of Pierre was specially studied by Beauvisage. This tree, the characters of which appear to approach the *Isonandra gutta* of Hooker and Serrulaz, grows in Cambodia, where the natives call it *Thior*, as well as in Cochin-China, where it is known under the name of *Chay*, yields an altogether inferior gum resin, which can only be used, at the most, in industrial mixtures of very doubtful value. This very striking botanical analogy between the *Dichopsis Krantziana* and the *Isonandra gutta*, and the surprising dissimilarity of the products which they

secrete, are explained by the difference in latitude, and entirely justify the remarks at the beginning of this chapter on the narrow and limited zone to which the production of gutta percha, possessing the qualities required by science and industry, is confined.

Dichopsis pustulatum of Pierre. This tree, found at Perak, succeeds well in Ceylon, where it is cultivated as a gutta percha producer. The French writers complain they have no information on this point, and that does not surprise them. If the culture at Ceylon has succeeded (the latitude and the climate, moreover, permit of this being supposed), the English they say will make use of the fact as long as possible without spreading the news. As a practical people, they keep the results of their experiments and researches to themselves. Let the

FIG. 110.—*Payena Lerii* (after Burck).

investigators of other nations do the same, and control the truth of the fact on the spot. The genus *Payena* supplies the *Payena Lerii* as almost its only guttiferous tree. Burck gives the botanical details of this variety of *Payena* :—

4. *Payena Lerii.—Folia e basi acuta ovalia v. ovalia-oblonga apice subito in acumen breve attenuata, nervis secundariis in folii substantiam immersis via conspicuis. Florum fasciculi axillares ad apices ramulorum conferti.* (*Azaola Lerii T. et B.; Keratophorus Lerii, Hassk, Ceratophorus Lerii, Miq.; Tuinbouw-flora, de Vriese; Beauvisage.*)

Folia e basi acuta ovalia v. ovalia-oblonga apice subito in acumen breve attenuata, coriacea; integerrima, margine subundulata, glabra supra lucida 5–10 *centim. longa,* 2·5–4 *lata, nervo medio supra prominulo, subtus prominente, nervis costalibus fere in folii substantiam immersis vix conspicuis, rectis patentibus ad marginem*

fere percurrentibus ibique arcuatum unitis. Petiolus tenuis 5–7 *millim. longus. Florum fasciculi ad apices ramulorum brevium conferti axillares sæpius ex axillis foliorum delapsorum* 4–8 *flori. Calycis laciniæ, rotundatæ, ovatæ aureo-sericeæ subæquilongæ, coriaceæ* 3 *millim. longæ. Corolla fere duplo longior extus et intus glabra, tubo* 2 *millim. longo, laciniis* 8 *oblongo-lanceolatis obtusis* 3 *millim. longis. Stamina* 16; *filamenta antheras subæquilonga glabra, antheræ ovatæ basi cordatæ connectivo adpresse-ferrugineo-piloso, supra loculos producto et apice penicellato. Ovarium conicum pilis dense obtectum* 10–12 *loculare. Stylus longe exsertus. Fructus carnosi obovato-oblongi, conici, medio scepius leviter curvati* 3–4 *centim. longi, styli rudimento apiculati. Semen unicum fereti-oblongum* 18–25 *millim. longum, hilo oblongo-laterali; testa coriacea nitida, fusca; albumen copiosum, albidum, corneum embryonem includens ejusdem longitudinis; cotyledones carnosa, applicativæ, radicula teres.* The gutta percha from *Payena Lerii* is known as *Getah Sundek* or *Soonie* or *Soondie*, the latter being the correct Anglo-Malay expression (in Sumatra, Banca, Borneo, Riouw, and Ambon).

The *Payena*, though likewise belonging to the *Sapotaceæ*, differs much more from the *Isonandra.* The small leaves are differently shaped and have a reddish tint when young. The flowers are white, and the fruit, which is fleshy and

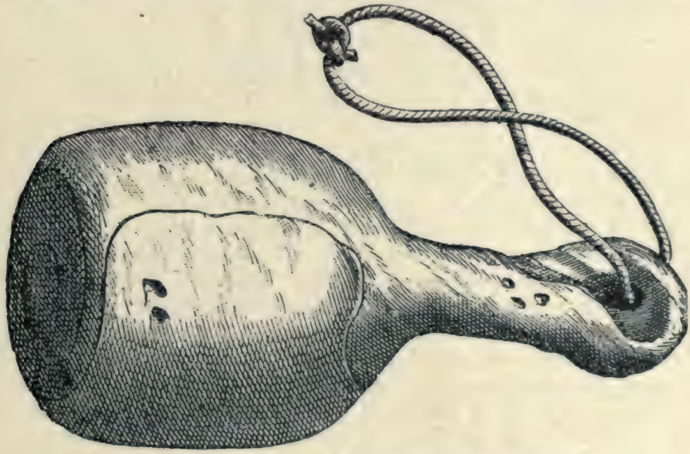


FIG. 111.—Cake of *Gutta Sandek* (after Beauvisage).

provided with a kind of horn, has a sweet taste and is eaten by the natives. Beauvisage analysed a plant found by Brau de St. Pol Lias in the Malacca Peninsula, and sent by him to the Paris Museum. This savant concludes from his analysis that the *Gutta Sandek* is none other than the *Keratophorus Lerii* of Hasskand. Without any doubt, the Malacca Peninsula must be regarded as the habitat of the *Payena Lerii*, one of the principal gutta percha producers, the gum resin of which is very widely distributed in commerce. In regard to the *Isonandra Benjamina de Vriese*, it is, according to Burck, none other than the *Payena Lerii.* De Vriese, after a rather short description of the plant, adds that the thick and coriaceous leaves are covered as with a varnish, and that the plant produces a superb red gutta, which much resembles that of the real *Ngiatoeh Merah.* The indigenous names of the *Payena Lerii* are *Ngiatoeh balam bringin* on the western coast of Sumatra, *Sandaï*, *Suntaï* in Sonpayang, *Sundeck*, *Sundeh*, *Sundi* on the eastern coast of Sumatra (Seligmann L.). *Gutta Souni*, often confounded with the gutta of the *Payena*, is simply a mixture of several resins of different botanical origin. *Payena Lerii* are met with on the upper plateaux of Padang (Sumatra), and also in other localities in Sumatra, in Banca, in Riouw, in Amboyna, and in Malacca; they are rather rare in Assaham (Sumatra), abundant at Siak (*id.*). The gutta percha which it yields is often mixed with *Bouha-balam*, which produces a

very inferior quality. The zone of culture of the *Payena Lerii* stretches from the seashore to an altitude of 500 feet, where the *Dichopsis oblongifolium* begins to be encountered. The *Payena Lerii* shares the low ground with the *Bouha-balam* tree; the *Payena* prefers dry ground, the latter marshy localities. The name of *Bringin*, which the *Payena* sometimes bears, arises from the resemblance of its leaf to that of the *Waringin* (*Urostigma Benjaminum*), cultivated successfully at Tijetpir.

5. *Balata.*—The genus *Mimusops* yields as guttifers the *Mimusops Balata*, the *Mimusops Globosa*, and the *Mimusops Schimperi et Kummel.* We give, according to Dr. Martin (*Flora Braziliensis*), the known botanical details of the *Mimusops Balata. Mimusops Balata* (Guertin) seems to be the same plant as *the Mimusops Balata* (Blume), the *Achras Balata* (Anblet), the *Lucuma mammosa* (de Vriese), and the *Sapota Mulleri* (Blume). *Glabra, foliis ovatis obovatis ovato vel obovato oblongis obtusis vel rotundatis, basi subacutis; pedicellus fasciculatis petiolum subæquantibus; lobis calycinis exterioribus* 3 *glabris vel minute fusco-puberulis, interioribus albido-velutinis, corollæ lobis sub anthesi reflexis, staminibus sterilibus ligulatis subintegris, antheris spiculatis ovario* 6–10-*gono loculariqe; bacca globulosa rotundato* 6–10-*gona. Rami crassi validi nodosi, cum ramulis teretibus crebre lenticellosis cortice obducti sordide fusco. Folia* $3\frac{1}{2}$–8 *poll. longa,* $1\frac{1}{4}$–$3\frac{1}{2}$ *poll. lata coriacea, supra glaberrima, fuscentia, subtus rufo-fusca ut plurimum glabrata, hic inde lepidote-albenti-subsericea, pilis minimis in pelliculam contiguam arctissime complicatis; costa centralis supra sulcata subtus semicylindrica, valida costulæ striiformes tenerrimæ, densissimæ vix conspicuæ. Petiolus pollicaris vel longior, subteres. Stipulæ* 2 *lix. lg. lanceolatæ. Florum fasciculi* 10–20-*flori. Pedicelli teretes sursum subincrassati, crebre, lenticellis linearibus flavicantibus obsiti, glabri vel minute parceque puberuli, pilis sublente solum conspicuis, longitudinum petioli ut plurimum æquentes, nunc paullo longiores, nunc breviores. Calycis* 3 *lin. longi lobi* 6 *ovato-lanceolati acuti, sub anthesi refracto, patentes v. subreflexi, intus glaberrimi fuscati, pube paginæ exterioris compositæ pilis minimis stellatim fasciculatis. Corolla calycis longitudine vel paullo brevior, lobis lineari-lanceolatis, acutis, extus glabris, intus levissime parceque puberulis. Filamenta staminum fertilium e basi subdilatata filiformi-subulata, antheris ellipticis basi cordatis subæquilonga, basi brevissime connata cum staminibus sterilibus dimidio brevioribus ovatis, obtusis sub coriaceis. Pubes minuta et parca in antherarum dorso facieque interiore filamentorum staminiumque sterilium et annuli basalis (per coalitionem illorum nati). Ovarium stylusque glabra, fabrica congenerum. Fructus globosus, apice paullulum depressus, rudimento styli apiculatus, vallibus levibus tot quot locula meridianaceis percursa, in sicco foliorum colore, cerasi magnitudine, elevationibus minutis scabratus; pericarpio crasso coriaceo; seminibus compluribus, rotundato-triangularibus, testa glaberrima lucida, pallide-ferruginea, area umbilicali parva, umbilico exserto. Albumen semini conforme, carnosum (sec. Gærtner album) in sicco rubescens. Embryo magnitudine albuminis, cotyledonibus foliaceis, sub pellucidis nervo centrali pluribusque lateralibus tenuioribus perensis; rostello cylindrico, brevi, obtuso. Habitat per Guyanam gallicum et anglicam in montibus Canuku, et ad ripas fluminis Barama, in Barbados et in aliis insulis antillensibus obvia: Teste Aublet ex insula Mauritii in Guyanam gallicam introducta est, ubi* pear-leaved mat-tree *vel* small-leaved mat-tree *dicitur. In Surinama vocatur* Bolletrie *v.* Bullet-tree *uti diversæ Sapoteæ.*

Botanical description of Balata according to Obacht.— The only natural substitute for gutta percha which really deserves that name is *Balata.* It is the coagulated latex of a large forest tree, belonging to the *Sapotaceæ*, which is known under the name of "bullet tree," "bully tree," or "bolletrie." The botanical name is *Sapota Mülleri Blume*, *Mimusops globosa Gærtner*, or *Mimusops balata Gærtner fil.* The tree reaches, at maturity, a height of 120 feet, and usually has a large spreading head. Its cylindrical trunk is 60 to 70 feet high, and 4 to 5 feet in diameter. The wood is hard, dense, and has a reddish tinge, which accounts for

the name of *paardenflesch* (horse flesh), given to it in the Dutch colonies. The glossy leaves are oblong-oval, 4 to 6 inches long, and 2 to 2¾ inches broad; they are acuminated, petiolate, and alternate, being crowded together towards the ends of the branches.

According to Rousseau, Venezuela produces *gum balata*, extracted from the *Mimusops globosa* (of Gærtner). The native Guarani give the name of *Mbea-r-ata*, and the Portuguese the name of *Purvio* or *Purgua*, to the resin. According to some samples which have been examined, there is no great difference between the products, and the *Mimusops globosa* especially may be confounded with the *Mimusops elata*. In regard to the *Mimusops Schimperi et Kummel* or *Abyssinian Mimusops*, botanical details are completely awanting. We shall have occasion to return to it when we treat on the chemical composition of gutta percha.

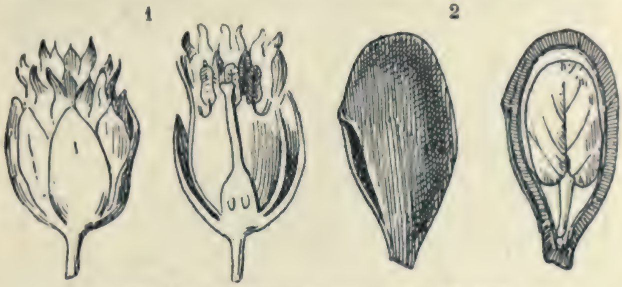


Fig. 112.—*Mimusops Balata* (after Baillon).
1. Entire flower and longitudinal section. | 2. Seed and longitudinal section.

The *Mimusopeæ* are distributed all over the globe, and not long ago Dr. Schweinfurth found the leaves of *Mimusops Schimperi Hochstetter* within the wrappings of Egyptian mummies 4000 years old. The bullet trees are found in Jamaica, Trinidad, Venezuela, British, Dutch, and French Guiana; they are also said to occur on the Amazon River. In the colony of British Guiana they are most plentiful between the east bank of the river Berbice and the Corentyn.

According to José Saldanha da Gama, other Brazilian *Sapotaceæ* should be capable of yielding gutta percha analogous with that called *Balata*.

The names of these are as follows:—

Table LXXXVIII.—List of Sapotaceous Plants which should yield Gutta Percha.

Mimusops elata	Maçaranduba.
Lucumus gigantea	Jàquà.
,, fissilis	Guaracuà.
,, lasciocarpa	Abiarana.
,, laurifolia	Guapeba vermelha.
,, procera	Maçaranduba brancha.
Chrysophyllum ramiflorum	Oaca.
,, ,,	Guaraità.

But only the first of these plants would appear to have been the object of any experiments in regard to the quality of its product, experiments which would not appear to have afforded very satisfactory results.

6. *Bassia Parkii.*—Amongst the *Bassia*, the *Bassia Parkii*, described by Ed. Heckel, Professor of the Faculty of Science, Marseilles (*La Nature*, 1885, 2 Sem., pp. 325, 370, 405), deserves special mention. "Amongst all the *Bassia*, large Indian or African trees, the seeds of which yield by expression fats, which find very useful application in industry under the name of 'Illipé Butter,' there is one which, more interesting than its congeners, remains ignored up to now so far

as regards one of its principal products (gutta percha), the whole value of which has been misconceived up to my researches. I refer to that one which, scientifically named *Butyrospermum* (*Bassia*) *Parkii*, *Kotschy*, is a native of Africa, where it bears the common name of *Tree of Karité*, *Ghee* and the fatty products of which, of buttery consistence, reaches us under the name of *Galaam Butter*, *Ghi Butter*, or, better, *Karité Butter*, and which is utilised in different ways in domestic economy by all the equatorial Africans. As the buttery product of this precious tree establishes, at least nominally, a point of contact between the two kingdoms of nature, the vegetable and the animal, I have thought that already from that point of view its history would be of real interest. But here this interest is doubled by what is adapted for the special habitat of the plant. Essentially African, the Karité tree belongs exclusively to that continent. Few researches up

FIG. 113.—*Bassia Parkii* (after Schweinfurth).

to now have been published on this subject beyond the now very old researches of Guibourt, and more recently the summary but interesting researches published by M. Baucher, naval pharmacist. These two unique works, notwithstanding the merit by which they are characterised, retain grave errors and important gaps in the history of this precious plant. It has therefore appeared to me necessary to again take up its study, and at the same time to endeavour, as far as I can, to spread the plant over the most diverse points of the tropical zone, and, in particular, in our French colonies." *Botanical description.*—*The Butyrospermum Parkii*, *Kotschy*, is a beautiful tree, reaching the height of 30 to 40 English feet, having a trunk of 1·50 to 1·80 metre (5 to 8 feet) in diameter, ramified like an oak, and yielding an abundant milky juice which easily coagulates (gutta percha.). Condensed at the top of large glabrous and rugose branches, the leaves are entire,

coriaceous, petiolated, and stipulated. Petioles measuring from 0·05 to 0·75 metre, glabrous, but pubescent at first; stipules lanceolated, sub-persistent, about 0·012 metre long, silky on the back; limb oblong, lanceolated, measuring 0·15 metre to 0·20 metre in length by 0·75 to 0·10 metre in width, widely cuneiform or rounded at the base, subcoriaceous, glabrous at maturity on the superior surface, highly pubescent underneath, furnished with twenty to twenty-five primary smooth open veins.[1] Flowers in umbels, springing from the axils of the leaves at the top of the branches; peduncles 0·012 metre to 0·025 metre or longer, thickly covered in their young state with a ferruginous nap. Calyx campanulate, coriaceous, with a short tube, and generally eight oblong lanceolated segments, the four exterior covered with a thick ferruginous down. Corolla, as long as the calyx, with a short tube and oblong, imbricated, glabrous segments. Stamens, opposite to the

FIG. 114.—Fruit and branch of *Bassia Parkii* (after Baillon).

segments of the corolla and inserted at their base; anthers oblong, lanceolate, measuring 0·003 metre, that is to say, half the length of the glabrous and awl-shaped filaments; pollen spherical, exhibiting four pores. Staminodes wide, oblong, pointed, dentate (like a saw) on their edges, which give them the appearance of fimbrication, shorter than the alternate stamens with the staminal filaments. Ovary globular, silky, ten-celled, each containing an anatropous ovule; style lanky, varying in length, sometimes inserted on the exterior, at other times included in the corolla (heterostyled dimorphism). Fruit ellipsoid (berry), with a thin solid pericarp and generally a simple seed, provided with very thick cotyledons. The fruit is of the size of an ordinary nut; it is furnished with a savoury sarcocarp, succulent and excellent to the taste. The seed is covered with a smooth thin

[1] Some of the measurements given in this sentence by the authors seem beyond all possibility. The proper reading of 0·75 metre is apparently 0·075 metre in each case.—TR.

crustaceous episperm of a maroon colour, which shelters a very bulky kernel without endosperm.

Synonyms—Habitat.—This plant is, moreover, known under the name of *Bassia Parkii* (De Candolle) and *Butyrospermum Niloticum* (Kotschy). Genus, *Sapotaceæ*, Lind. End. Oliver. (*Bassia Butyracia*, Roxburgh.) (Branch and fruit.) Upper Guinea, kingdom of Bambara, where it was discovered by Mungo Park, in the Niger country, at Nupé, Ieba, etc., Abbeokuta (of Irving and Barter) in the Nile country, the White Nile, Gondo Koro, Djur, Kosanga, and the countries of Niams-Niams, Madi. To these localities or stations we may add the following, which is more exact:—The Karité is very well known in the valley of the Upper Niger and in that of Bakoy and of Baoulé and their affluents; real forests of it are found in the Bélédonga, the Fouladougon, the Manding, the Guenickalaris, etc. (Exploration of the Upper Niger by Commandant Gallieni). According to Baucher (*Archives de Médecine Navale*, t. xl., November 1883), it grows spontaneously in the argilo-silicious, ferruginous, gravelly, and fissured soils which are met with in the plains of Upper Senegal when the Niger route is taken. In a general way, it may be said to exist throughout the whole of the valley of the Upper Niger, *i.e.* in all the country situated to the east of the old French Senegalese possessions before their penetration into the Soudan. It is especially well known amongst the Bambaras, particularly in Bélédonga. It is already reported in Bomé and to the east of Fouta-Djallon, where it is better known under the name of Karé. It is very well known in Segon and Timbuctoo. In the Nile region, Schweinfurth mentions it amongst the Bongos, the Mittous, and the Niams-Niams. We are going to show that the *Bassia* may be classed in the first rank alongside the *Isonandra*, the product of which it imitates so much as to be mistaken for it.

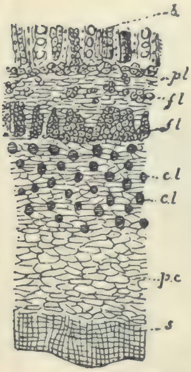


FIG. 115.—*Bassia Parkii*, cross section of a young branch.
s., suber; *p.c.*, cortical parenchyma; *c.l.*, laticiferous canals; *f.l.*, liberian fibres; *p.l.*, liberian parenchyma; *b.*, wood.

Microscopical examination of a section of a young branch of Bassia.—If we examine the section of a young branch of this tree, we observe that the laticiferous vessels *c.l.*, arranged in packed circular rows, are situated in the centre of the cortical parenchyma *p.c.*, itself placed under a tuberose not very thick layer *s.* It is therefore easy to reach them at once by means of any cutting instrument. It is the same with the young stem; but when arrived at maturity, both in the caulinary system and in that of the young branches, there is produeed in this same parenchymatous tissue numerous secondary ligneous formations, very near to each other, arranged in circles, and composed of an abundant, very resistant wood *b*, and of a very reduced liber *f.* The growths, on account of their rapid development, almost touch each other, and thus form a protective barrier, behind which are hidden the vessels of the latex, driven into a corner against the wood. It then becomes difficult, if not impossible, to reach the laticiferous vessels: thus, it is only possible by a deep cut from a powerful instrument to make an incision capable of giving vent to an abundant flow of milk, in the case of adult stems or branches. This abnormal constitution is present, without doubt, in all the *Bassia*, the result of which is to render the whole of them equally refractory to the necessary cortical incision. All the difficulty consists in the necessity of breaking or, better still, of removing this barrier. This resistance, once conquered, the operation gives birth to a thick white milk which very easily solidifies, and, coagulated by the same process as gutta percha, gives eventually a product comparable with that of the *Isonandra*. *The Madar gutta of India.*—The inspissated and sun-dried sap (milk) from the stem of the *Callotropis procera* constitutes the *Madar* gutta of India. Hooper (Rept. Labor. Ind. Mus. (Indus. Sec. 1905–06)) describes it as a pseudo-gutta, with the composition:—Resin, 52·9;

insoluble, 37·9; ash, 9·2 = 100. It contains albane and fluavile resins in large amounts. This tree is not only the one most frequently met with in the vast tracts of sandy deserts of Central India and Rajputana and Sind, but it is almost the only form of plant life encountered. It seems to act as the pioneer plant in the reclamation of barren land. An outlet for its products is thus greatly to be desired. Cultivation and selection might lead it to be the recognised tree for poor soils. But unless the shoots cut for fibre could be tapped for milk, it is improbable that tapping for gutta alone would pay, as stem and twigs are too small. Besides, the resin has the disadvantage of conducting electricity fairly well, which debars it from being marketed for insulation purposes. The milk changes vegetable blues to green instead of reddening them.

Botanical summary.—Here terminates the enumeration of the different varieties of *Sapotaceæ* known as capable of yielding commercial gutta percha. But the question has not yet been sufficiently studied so as to close definitely the list of the *Sapotaceæ* capable of producing gutta percha or a similar substance. Not only have the known species not been sufficiently studied, but we do not know some Borneo species which are included in the herbaria of Buitenzorg or Saigon, but which have never yet been met with living, at least by Europeans. Again, no species from the eastern watershed of the Malay Peninsula, and especially from the State of Pahang, has yet been examined in a complete manner. It is the same with the species of equatorial Africa and of India. It will require a number of years yet before we can lay down some reliable data on the plants of these regions capable of yielding commercial gutta percha. For reference purposes the few plants belonging to other orders than the *Sapotaceæ*, and, rightly or wrongly, reputed as guttiferous, are enumerated below, but they are merely indiarubber-bearing plants, yielding a less sensitive and a less elastic rubber, and not guttiferous plants :—

Asclepiadeæ—	
Cynanchum viminale	Hindostan.
Callotropis gigantea	,,
Asclepias acida	,,
Apocyneæ—	
Alstonia scolaria	,,
Euphorbiaceæ—	
Euphorbia trigona	Hindostan and the Cape.
,, nereifolia	,, ,,
,, tortillis	,, ,,
,, tirucalli	,, ,,
Macaranga tomentosa	,, ,,
Pedilanthus tithymaloides	,, ,,

To conclude, we give in Table LXXXIX. the nomenclature of the principal varieties of the guttiferous species or reputed as such, whilst admitting with M. Serrulaz that this long list is due probably to the fact that the shape and dimensions of the leaf vary enormously with the age of the plant and with the parts thereof, and that a great number of the species introduced into botany from branches deprived of floral elements and not comparable amongst each other will disappear in proportion as observations have been more often controlled on the spot on a fully developed plant.

[TABLES.

TABLE LXXXIX.—SYNOPTICAL TABLE OF

Family.	Tribe.	Variety.	Scientific Synonym.	Local Synonym.
SAPOTACEÆ.	Palaquium or Dichopsis.	Palaquium gutta.	Isonandra gutta. Dichopsis gutta.	Gueutha-Tuban-Merah.
id.	*id.*	Palaquium oblongifolium.	Dichopsis oblongifolium.	Mayang Doerrian. Njatoeh - Balam - Tembaga. Njatoeh-Balam-Sirah. ,, ,, Soeson (in Sumatra). Njatoeh - Balam - Doerrian. Ka - Malan - Paddi (in Borneo). Gueutta - Taban - Merah (western coast of the Malay Peninsula).
id.	*id.*	Palaquium borneense.	Dichopsis borneense.	..
id.	*id.*	Palaquium Treubii and variety parvifolium.	Dichopsis Treubii and variety parvifolium.	Dadauw.
id.	*id.*	Palaquium Vrieseanum.	Dichopsis Vrieseanum.	Njatoeh-Bindaloc.
id.	*id.*	Dichopsis callophylla.	Isonandra chrysonata Isonandra chrysophilla. Isonandra costata. Isonandra oblongifolia.	Mayang Batou. Njatoeh-Djankar.
id.	*id.*	Palaquium Selendit.	..	Halaban. Njatoeh-Selendit. Mayang-Korsik. ,, Sikkum. ,, Djerinjin. ,, Kartas.
id.	*id.*	Palaquium Njatoeh.	.	Njatoeh.
id.	*id.*	Palaquium Pistulatum.	..	..
id.	*id.*	Dichopsis elliptica.	..	Pauchontee.
id.	*id.*	Palaquium Kranziana.	.	Thior in Cambodia. Chay in Cochin-China.
id.	Payena.	Payena Lerii.	Keratophorus. Isonandra Benjamina. Azaola Lerii.	Njatoeh-Balam-Baringin. Njatoeh-Balam - Waringin. Njatoeh-Balam-Sundeck ,, ,, Soendai. ,, ,, Sandai. ,, ,, Soentai. ,, ,, Pipis. Balam Tandjong. ,, Tjabee. ,, Tandock. ,, Troeng. ,, Soute. (All these denominations belong to Sumatra.) Koelan (in Banka). Njatoeh Ka-Malam (in Borneo), Ranas. Balam Soentai (Riouw). Gutta-Selendit (Malay Peninsula).

THE PRINCIPAL GUTTIFEROUS PLANTS.

Botanists and Explorers.	Habitats (known).	Remarks.
Th. Lobb. Dr. Oxley. Hooker. Bentham. Burck. Brooke. Seligmann Lui. Baillon. Serrulaz. Beauvisage.	Malasia-Singapore (mountains of that isle, at Chasseriau Estate, ravine of Bouquett-Timah). Borneo? Cultivated at Tijetpir, Java.	It is this species which, rightly or wrongly, would appear to yield the best specimens of gutta percha. However that may be, it would not appear to exist nowadays except in very rare cases, and would appear to be completely neglected for the following species. "While *Palaquium oblongifolium* (Burck) is but a variety of *P. gutta*, still by certain writers it is held to be a distinct species, and to yield the Taban Sutra of Perak" (Watt).
Seligmann Lui and Vesque. Beauvisage. Brau de St. Pol Lias. Teysmann. Burck.	In all parts of Sumatra, especially at Loche-Along (eastern coast), Lampong. South-west of Borneo (Pontinak). South of Borneo (Banjermassin). Rhio Archipelago. Malacca. Perak. Cultivated at Tijetpir, Java.	It is unquestionably the guttiferous tree *par excellence* as regards quality. Balam-tembaga is, in Malay, yellow copper leaf. The plant, shrinking from drought, is satisfied with mediocre exposure. Deposit of calcium oxalate in the leaves. Abundant colourless transparent latex. Alkalies do not colour it. The Taban Merah, according to Burn Murdoch, is *P. oblongifolium*; Taban Chaier is *P. sp.*; Taban Puteh is *P. pistulatum*; and Taban Back is *P. sp.*
Teysmann.	Borneo. Cultivated at Tijetpir, Java.	These three species are only varieties of *P. oblongifolium*. The quality of the gutta percha is the same. But the Netherlands authorities in Java have demolished their *P. Treubii* plantations as inferior and to prevent hybridisation.
Burck.	Isle of Banka. Tijetpir plantations of this variety demolished as gutta was inferior.	
Burck.	Sumatra (Mount Sagoh).	
Benth. and Hooker. Pierre. De Vriese. Teysmann. Seligmann Lui and Vesque.	Borneo.	Yields a brighter and redder gutta than *P. oblongifolium*. Its fibre is not so fine and perhaps not so rigid. The Mayang Batou, according to Vesque, approaches the Palaquium of Pierre, but is not identical. It would appear to be better adapted to stand drought and to support more intense light than the *P. oblongifolium*.
Seligmann Lui and Vesque. Burck.	Sumatra. Malay Peninsula.	Very hard gutta, unfit for cable manufacture. A plant relatively well adapted to stand short droughts. Very mediocre light (exposure to sun).
Teysmann.	Java (province of Banjevang).	..
Pierre.	Perak, Ceylon.	Cultivated rationally and successfully by the British.
..	Wynaad, Coorg, Travancore (British India).	Horny resin, brittle in the cold.
Pierre.	French Protectorate of Indo-China.	Only yields a defective product, probably owing to climatic conditions.
Benth. and Hooker. Miquel. De Vriese. Seligmann Lui and Vesque. Beauvisage. Burck. Teysmann. Tromp. Hasskari. Brau de St. Pol Lias.	Sumatra (Padang, Assahan, and Siak). Banka. Borneo. Rhio Archipelago. Amboin. Malacca. Tawi-Tawi. Philippines.	Owes its name of Baringin or Waringin to the resemblance of its leaves to those of the *Urostigma Benjamin*—in Malay, Baringin or Waringin. This is the gutta percha which enters into the majority of the commercial mixtures which come to our markets under the name of raw gutta percha. The gutta percha wants homogeneity. The tree arrives at maturity sooner than the *P. oblongifolium*. Cultivated by the British at Pardenia and Heneratgoda. All the tissues of the plant contain a substance which blackens with alkalies in absorbing oxygen, possibly due to Kurz transferring *Keratophorus Lerii* to *Payena*, but his Burmese species is different from above. *P. Lucida*, an evergreen tree of Assam, Tenasserim, and the Straits, yields gutta percha. *P. Maingayi* (Clarke) of Penang and Malacca abounds in gutta percha (Clarke).

TABLE LXXXIX.—SYNOPTICAL TABLE OF THE

Family.	Tribe.	Variety.	Scientific Synonym.	Local Synonym.
SAPOTACEÆ.	Payena.	Payena macrophylla.	Kacosmanthus macrophyllus.	Goetah Moendirig.
id.	Bassia.	Bassia Parkii.	Bassia Butyrospermum ,, Niloticum. ,, Butyracea.	Tree of Charity. Ghi tree. Saga.
id.	Mimusops.	Mimusops Balata.	Mimusops Balata. Achras Balata. Lucuma mamosa. Sapola Mullerii. Higucrona. Mastota.	Small-leaved or pear-leaved mat tree. Bullet tree or Bolletrie. Manyl-Kara. Fresh or bleeding Balata. Red Balata. Galibis Balata. Muirapiringa.
id.	Mimusops.	Mimusops globosa.	..	Purvio. Purgua. Mbea-r-ata (hard thing) in Guarani.
id.	Mimusops.	Mimusops elata.	..	Maçaranduba. Apraiu.
id.	Mimusops.	Species.	..	Maparauba.
id.	Mimusops.	Species.	Lucuma gigantea. ,, fissilis. ,, lastiocarpa. ,, laurifolia. ,, procera.	Jaqua. Garaqua. Abiarana. Guapeba vermelha. Chana or White Maçaranduba.
id.	Mimusops.	Mimusops sp. ,, speciosa. ,, Schimperi. ,, Kummel.	Abyssinian Mimusops.	Cafequesu.
id.	Chrysophyllum.	Chrysophyllum ramiflorum. Chrysophyllum species.	..	Baca, Guarita. Leitero de Mato.
id.	..	Achras Australis. Sano Manilla. Imbricaria coriacea.	..	..
ASCLEPIADEÆ.	Cynanchum. Callotropis. Asclepias.	Cynanchum viminale Callotropis gigantea. Asclepias acida.	..	Madar or Akanda Chatwan.
APOCYNEÆ.	Alstonia.	Alstonia scolaris.	..	Kath Mandu.
EUPHORBIACEÆ.	Euphorbia. Macaranga. Pedilanthus.	Euphorbia trigona. ,, nereifolia. ,, royleana. ,, tortilis. ,, tirucalli. Macaranga tormentosa. Pedilanthus tisthymaloides.	Species which may be classed amongst the rubber guttas; otherwise little studied.	Milk hedge or bush.

PRINCIPAL GUTTIFEROUS PLANTS—*continued.*

Botanists and Explorers.	Habitats (known).	Remarks.
De Vriese. Teysmann. Hasskari. Miquel. Beauvisage. Burck.	Java (province of Bantam).	Of very inferior quality to the preceding.
Linnæus. De Candolle. Roxburgh. Kotschy. Guibourt. Baucher. Heckel & Schlagdenhaufen. Mungo Park. Gallieni. Schweinfurth.	Upper Guinea. Roy of Bombara. Upper Niger, White Nile, country of the Niams-Niams, Bakoe valley, Baoule, the Beladongo, the Feladongo, the Mandiarg, the Guenickalaris, in the Bougos.	According to Heckel, the Bassia would be an African guttiferous plant capable of competing with the Palaquium of the Straits Archipelago. *Bassia Mottleyana de Vriese* (Kotian of Malacca and Borneo); latex an inferior gutta. Three samples of *B. latifolia* latex from Hoshangabad averaged 48·9 gutta, 38·8 resin, and 12·3 ash. It was light grey plastic, but yield per tree small. Latex of *B. longifolia* from Tinnevelly gave 22·6 gutta, 62·7 resin, and 14·7 ash.
Aublet. Gærtner. Dr. Martin. Blume. De Vriese. Schomburgk. Santa Anna de Nery. Biolley.	French, British, and Dutch Guinea. Mount Canukut. Rivers of Barama. Surinam. Barbadoes. West Indies. Brazil (Amazonia). Costa Rica.	Intermediate between rubber and gutta percha. Although its density is near enough to gutta percha, it is not ductile enough to be used for covering wire, and can only be used for this purpose when mixed with very good gutta percha. Softer at the ordinary temperature, it does not harden so much on cooling as ordinary gutta percha, from which it differs essentially by the manner in which it behaves in the air. Whilst gutta percha, exposed to the air and light, is rapidly transformed into a hard, brittle, and resinous substance, a transformation which eventually penetrates the whole mass, balata, on the contrary, remains for a very long time without any perceptible change.
Gærtner. Rousseau.	Venezuela (province of Maturia).	Same properties as the preceding; may be confused with it.
Bernardin da Silva Continho.	Brazil. Venezuela (Inirido and Guavaire).	May be classed amongst the series of rubber guttas. Harder than Mimusops Balata.
..	Brazil.	As above.
..	Brazil.	
..	Angola. Gaboon. Abyssinia.	All these scarce and little known species require to be better studied before it would be possible to classify them in any satisfactory manner. Species examined more especially by Heckel and Schlagdenhaufen. In addition to these there are the Indian species—*M. Kauki*, *M. Elengi*, *M. Hexandra*, *M. Roxburghiana*—in regard to which no effort has been made to see whether latex might not be of similar value to Balata.
..	Brazil. Niger.	
..	Queensland. New South Wales. Madagascar. Maurice Island.	
..	British India.	..
.	*id.*	..
Haworth.	India and the Cape.	..

TABLE XC.—ANALYSIS OF GUTTA PERCHAS OF KNOWN BOTANICAL ORIGIN (WRAY'S PERAK SAMPLES).
Received at Kew, 1883–84 ; *analysed* 1885 (OBACH).

No.	Percentage Composition.				Totals.		Ratio.		Percentage Composition.	
	Gutta.	Resin.	Dirt.	Water.	G. P. (G. + R.).	Waste (D. + W.).	G. P. Waste.	Gutta Resin.	Gutta.	Resin.
(1)	84·3	10·7	3·7	1·3	95·0	5·0	19·0	7·9	88·8	11·2
(2)	77·1	16·9	4·6	1·4	94·0	6·0	15·7	4·6	82·0	18·0
(3)	47·0	48·4	3·6	1·0	95·4	4·6	20·7	1·0	49·3	50·7
(4)	45·3	49·6	3·4	1·7	94·9	5·1	18·6	0·9	47·8	52·2
(5)	23·1	71·5	4·2	1·2	94·6	5·4	17·5	0·3	24·4	75·6
(6)	43·9	37·6	5·1	13·4	81·5	18·5	4·4	1·2	53·9	46·1
(7)	31·6	65·2	1·8	1·4	96·8	3·2	30·2	0·5	32·6	67·4

(1) *Dichopsis oblongifolia* (Burck) (getah taban sutra) (silky), nearly white, clean, New Kennering, Upper Perak, 1884, yielded light brown elastic prime gutta, and yellow very soft resin.

(2) *D. Gutta* (Benth. et Hook.) (g. t. merah) (red), very light pinkish, clean, River Plus, Upper Perak, 1883, yielded light pinkish elastic prime gutta, and brownish yellow very hard resin.

(3) *D. Polyanthe* (Benth.) (g. t. puteh) (white), clean, Waterfall Hill, 2500 feet, Larut, 1883, yielded light brown elastic gutta, and light brown brittle resin, a moderate sized tree of Cachar, Chittagong, Arakan, and Pegu.

(4) *D. Pustulata* (Hemsely) (g. t. chaier) (liquid), white, dense, clean, Waterfall Hill, 600 feet, Larut, 1884, yielded light brown elastic gutta, and light brown very brittle resin.

(5) *D. Maingayi* (Clarke) (g. t. simpor), nearly white, clean, crumbly, Changkat Serdang, Larut, 1884,—a better sample, also from Wray, received 1886, analysed 1896, gave 93·5 G. P. (1 part gutta, 2 resin),—yielded light pinkish brown elastic gutta, and very light hard resin. A tree of Penang and Malacca abounds in gutta percha Maingay.

(6) *Payena Lerii* (Burck) (g. sundek), nearly white, dense, clean, Tapstang, near coast, Larut, 1884, yielded light pinkish elastic gutta, and pale yellow nearly liquid resin.

(7) *Bassia Motleyana* (Clarke) (g. gahru), the *Kotian*, a tree of Malacca and Borneo, nearly white, clean, crumbly, Waterfall Hill, 2000 feet, Larut, 1884, yielded white very brittle gutta and light hard resin.

CHAPTER II

CLIMATOLOGY—SOIL—RATIONAL CULTURE

If it has been possible to give with certainty some information on the climatology which rules the growth of indiarubber-bearing plants, it is not so in the case of guttiferous plants. How could it be otherwise, since at the present day no one is agreed as to the plant producing the best commercial gutta percha, any more than on the producing countries? Seligmann Lui is the only one who, in his examination of the guttifers of Sumatra, has attempted an essay on the climatology of the gutta percha *mayangs* (trees). The opinions expressed by this French telegraphic engineer are entitled to respect. This part of his work is therefore given in full. "The Straits Archipelago, of eruptive origin, with several volcanoes still in full activity, exhibit, owing to this activity, two very distinct kinds of soil. In the centre is a mountainous, sometimes very elevated, region. The rivers, in the rainy season, receive an enormous mass of water. They descend with impetuosity, and cut up the banks of the higher valleys into deep ravines, thus becoming charged with a considerable quantity of mud, which they deposit farther on, when the current has spent itself to a great extent. There are thus formed, at the foot of the mountains, belts of flat ground, which extend daily, and which, below sea-level, are prolonged by banks to a great distance from the coast. Of these alluvial deposits, the most recent are still half under water; their shape and arrangement are altered daily, and this inextricable labyrinth of muddy moving islets disappears under the foliage of the mangroves and the water palms. Beyond, older deposits, already dried up by the sun, form a firm but absolutely flat soil, of no great height, and often flooded by the rise of the rivers. In these very fertile parts are the establishments of the Malay population, who have established some clearances. It is there also that the Europeans have started some plantations, and grown tobacco at Delli and at Langkat, cinnamon and tapioca at Benkalis, cane-sugar, coffee, and pepper at Palembang and on the western coast. Higher up—in fact as soon as the first movements of the soil embank the rivers in the deeper valleys, and prevent overflowing, as soon as, consequently, the rocky soil commences to emerge from the thick layers of transported soil—we enter into the regions of the large forests. It is there, on banks of sandstone, covered with scanty humus, that we come across the *mayangs* (the gutta percha trees). Numerous streams, which do not dry up during the dry season, and frequent rains, spread over the whole of the year, preserve the freshness and humidity of the soil. The altitude is still too low for the temperature to be perceptibly lowered, and, on the coast, the average, during the coolest months of the year, does not go below 25° C. (77° F.). I will not venture to affirm that these are the only conditions of soil and climate adapted to the *mayangs* (*Palaquium and Payena*). All I can say is, that such is the case there, where I have seen these trees, and it was likewise there that Murton encountered them before me." The considerations formerly elaborated on the subject of the geographical distribution of *mayangs* have left no illusions in the minds of the true explorers of the guttiferous countries. They have not been able to find those plants in the wild state beyond the guttiferous zone. All regard the researches of Pierre, in Cochin-China, as in this respect futile. The *Thior* is merely a bad quality rubber, and can in no way be regarded as even an inferior

gutta percha. The plants to which the same writer drew attention in no way respond to the Sumatra species. Seligmann Lui ascertained, at Bangkok, that an Englishman, in the service of Siam, had brought gutta percha back with him after a journey to the environs of Pre-Tcha-Bouri, situated in the centre of the Gulf of Siam, on the western coast, towards the 13° of N. latitude. That engineer found that the substance in question was none other than Borneo rubber, which is likewise found in Burmah, on the Pegu coast. The second king, who is especially interested in these matters, affirms, moreover, that gutta percha exists at Trigano, but not higher.

Acclimatisation.—There is nothing astonishing in the fact that the *difficulties of acclimatising the mayangs* are almost insurmountable beyond the guttiferous zone, and, in localities under the sphere of French influence, there are local obstacles such as the torment of the wind in the mountains of Kamchay, then general obstacles such as the nature of the country. Seligmann Lui well remarked that the natural zone of habitat is limited to about the 5° of N. latitude, and the French possessions are situated beyond the tenth parallel. There is also the difference in climate between French establishments and the isles of the Straits Settlements. In Java and Sumatra, near the coast, the average winter temperature does not fall below 25° C. (77° F.), whilst at Saigon it falls to 22° C. (71·6° F.). This difference is much more perceptible in the rainy regions. In the Malay Archipelago the annual rainfall exceeds 2 metres (78·6 inches), whilst in Cochin-China it varies between 1 and 2 metres (39·3 and 78·6 inches). The rainfall is, moreover, distributed in a different way. In Malasia there is not, properly speaking, any dry season, and—after winter time, during which the periodical rains, heralded in by the south-west monsoon, prevail—frequent showers constantly enrich the soil. But in Cochin-China and Cambodia, after a season of daily storms, another of absolute dryness is endured. Trees transplanted into a soil under an unsuitable climate will perish, or, at best, are sickly and degenerate; they grow, but only yield produce of an inferior quality. To these difficulties, in the experimental acclimatisation of guttiferous trees—not insurmountable difficulties if the experiments be conducted within the guttiferous zone—other great difficulties have to be added. As recognised by Seligmann Lui, it is not the *electric properties* or the *plastic properties* which alone characterise a good gutta percha, but also its *durability.* Since the time of the construction of the first cables, we have tried to increase the insulation by different processes: by a mixture of different kinds, this has been done much beyond what is necessary. But of the substances employed, how many are as durable as the pure products of superior quality used in the beginning? Whatever results may be obtained in the laboratory, great stress should be laid on that important element, previous experience. If a new gutta percha appears to present advantages, without doubt its culture should be attempted, but as an experiment only, as such gutta percha has not been proved. But substances the value of which has been determined long before, ought to inspire quite different confidence. In the first rank of the latter, Seligmann places *gutta-derrian* or *taban.* White, when pure, this product is generally tinted brownish red by foreign matter. It has all the appearances of a good gutta percha. It is the quality most highly esteemed on the market, and it is it, without doubt, which was exploited in the first instance. We fell back on other kinds when this became rare. According to the same writer, the second place always belongs to *gutta sundek* and *gutta-babou*; this is also in accordance with commercial tendencies. *Gutta-sundek* exhibits a white compact mass, the smooth and brilliant cut of which has the appearance of ivory. Generally, the products placed on sale have a reddish colour, due to the mixture of gutta percha, properly so called, produced from the latex, which circulates between the bark and the wood, with a coloured juice, which flows from the exterior cortical tissue. This gutta percha would appear to be less plastic than the *derrian.* The *gutta-babou*, of a brighter and redder colour than the *derrian*, has not so fine a tissue. It is, perhaps, also more rigid. The *guttas*, *belouk* and *gapouk*, confused in commerce under the name of

gutta-pouteh (white), are but little esteemed. They exhibit, in fact, a property which makes them closely approach the *gutta* called *bouhâ-balam*, a substance from the lower isles and marshy lands, which is of no value. It becomes friable and pulverulent after a comparatively short time. Future conscientious and intelligent researches will show whether this transformation is a simple physical change, or whether the phenomena of oxidation and resinification observed in the case of all old gutta perchas are produced more rapidly in these two kinds. They will show whether the heating processes are capable of preventing or retarding these phenomena, or whether we should abolish the use of these substances, at least for telegraphic purposes, on account of their short durability. They would then find their use in certain industries, where the low price will compensate for the prompt deterioration, as in electro-metallurgical moulds. The *mayang* producing the latex of the *gutta derrian* may, at any rate, be used in rational culture and transplantation experiments. The value of the other species will be ascertained when long and delicate researches have thrown light on the subject. To elucidate this point, not only should the electrical properties be examined, insulation, and specific inductive capacity, but all the other physical and chemical properties—whether the gutta percha be elastic, its behaviour towards heat, at what temperature it softens, what consistency it assumes after having been melted, how it resists oxidising agents, if it be permeable to water under pressure, etc. etc. And when the answer to so many questions has been favourable, when prolonged trial has been joined to the testimony of experience, then only will be the time to reply and to propagate the new culture. As the results of these researches, shall we get better results than that afforded by *gutta-derrian*? It is possible; but if to the fifteen to twenty years required before a plantation yields its first products we add the number of years which will be required for the durability test to be conclusive, we throw any conclusion back thirty to forty years.

TABLE XCI.—ANALYSIS OF COMMERCIAL SAMPLES ON BOUNDARY OF GEOGRAPHICAL AREA OF GROWTH OF GUTTA PERCHA TREES (OBACH).

No.	Percentage Composition.				Totals.		Ratios.		Percentage Composition.	
	Gutta. G.	Resin. R.	Dirt. D.	Water. W.	G. P. (G. + R.)	Waste. (D. + W.)	G. P. / Waste.	Gutta. / Resin.	Gutta.	Resin.
(1)	68·5	18·1	11·9	1·5	86·6	13·4	6·5	3·8	79·1	20·9
(2)	42·0	14·4	16·9	26·7	56·4	43·6	1·3	2·9	74·5	25·5
(3)	50·4	12·9	12·6	24·1	63·3	36·7	1·7	3·9	79·6	20·4
(4)	31·7	26·0	22·3	20·0	57·7	42·3	1·4	1·2	54·9	45·1
(5)	72·8	13·6	9·5	4·1	86·4	13·6	6·4	5·4	84·2	15·8
(6)	41·5	19·5	14·0	25·0	61·0	39·0	1·6	2·1	68·0	32·0

(1) N.N.E. (or) British North Borneo; light brown, little fine bark.
(2) E. (within), Coti, Borneo; brown, grey, woody.
(3) S.S.E. (well within), Banjermassin, Borneo; light pinkish brown, woody.
(4) S.S.W. (within), Lampong, Sumatra; brown, woody.
(5) W. (without), Achin, Sumatra; light brown, dense, clean.
(6) N.N.W. (within), Penang, Malacca; brown, much fine bark.

The questions of soil, climate, and cultivation of gutta percha are long and difficult ones. Many years must pass before science can definitely decide the point. The British have prosecuted these experiments for a long time. Choosing the island of Ceylon as an experimental field, they are within the territorial limits essential to success; and if Pierre, in Cochin-China, has had no chance of producing any results, it is to the zone selected to which the unsuccess must alone be attributed. Were these same experiments resumed in the line, more near to the Equator, of the new French African possessions, the French imagine that they

also would be in possession of a real gutta percha market, in addition to their excellent indiarubber market. But all plants, in order to prosper, ought to be able to enjoy a minimum, though variable, quantity of heat and moisture. The minimum qualities ought to be exactly determined for each species. To be at fault in any of those requirements in any acclimatisation experiment is to court a check. The plants submitted to a régime which is not theirs are doomed to die; and if death spares them, the impoverishment is such that complete degeneration takes place, not only in regard to the vigour of the foliage, the trunk and branches, but also in their productive value, whatever it may be. An example amongst many will make this better understood. In Europe the stem of our hemp produces textile fibres. Transplanted into India, the same grass produces a resinous volatile oil, known under the name of *Ganga*, with very energetic narcotic properties. The resin is evidently formed at the expense of the fibre, which becomes useless, and no longer furnishes anything but bad fuel.

The Netherlands Indian Government gutta percha plantation in Java.—Dr. W. Burck, who in 1883 received an order from the Netherlands Indian Government to institute an inquiry regarding the gutta percha yielding trees, claims the credit of having brought to light the trees which produce the different kinds of gutta percha collected by the natives. From his researches it appeared that the gutta percha which is specially needed for the cable industry was only obtained from a very few species of trees, whose presence in the forests was becoming more and more rare. According to Burck, they are trees belonging to the family of *Sapotaceæ*, namely,—the genus *Palaquium*, from which *Pal. oblongifolium*, *Pal. borneense*, and *Pal. gutta* yields the best gutta percha. The existence of these trees is limited to a small area extending to 6° on either side of the Equator, and from 99° to 119° E. longitude. As may be seen, the greatest part of this area lies in Netherlands India, where also the largest quantity of gutta percha is obtained.

When, through the researches of Burck, Wray, Seligmann, Serullaz, and van Romburgh, the veil which hid the mystery of gutta percha and its origin was lifted, it also became known that, unless measures were taken, the gutta percha yielding trees, owing to the ruinous manner of collecting adopted by the natives, would be entirely exterminated in a very short time. Already in the forests of Borneo and Sumatra, in the neighbourhood of rivers, no gutta percha trees are to be met with, and the natives have to travel for days into the jungle to find them. What the position would be if the 236,840 miles (439,047 kilometres) of submarine cables now in use had to be renewed, can easily be understood, if it is known that for 1 kilometre of cable about 25 kilogrammes of gutta percha of the best quality is required, and a fifteen- to twenty-year-old tree when felled yields no more than 400 grammes of the product. For the insulating of 236,840 miles of submarine cable it would thus be necessary, at a moderate estimate, to fell fully 27,000,000 gutta percha trees. With these figures before them, and bearing in mind the great interest that all civilised nations have in common in the continued existence of the submarine cables, the Netherlands Indian Government soon realised that on their part steps must be taken to prevent the entire extermination of the gutta percha yielding trees. Although it was at first thought that this object would be obtained by a sharper control over the collecting, whereby the natives would be forbidden to fell trees below a certain measurement, it soon appeared in practice that the maintenance of these regulations in the almost inaccessible, uninhabited, virgin forests of Sumatra and Borneo was most difficult, if not impossible. Notwithstanding the fact that repeated attempts have been made to replace gutta percha by some other insulating material for submarine cables, these efforts have not, up to the present, been crowned with success. The determination to discover other insulating materials was due to the fact that with the considerable extension of the submarine cable-net a proportionately greater use was made of gutta percha. There was thus every reason for anxiety as to whether in the future the necessary quantity of gutta percha could be reckoned

upon for the manufacture of submarine cables. As so little was known regarding the trees which yielded the so valuable gutta percha as already mentioned, one French (Seligmann Lui), one English (Wray), and one Dutch (Burck) expedition was fitted out with the object of throwing light upon the matter.

On the advice of Professor Treub, Director of the Botanical Gardens at

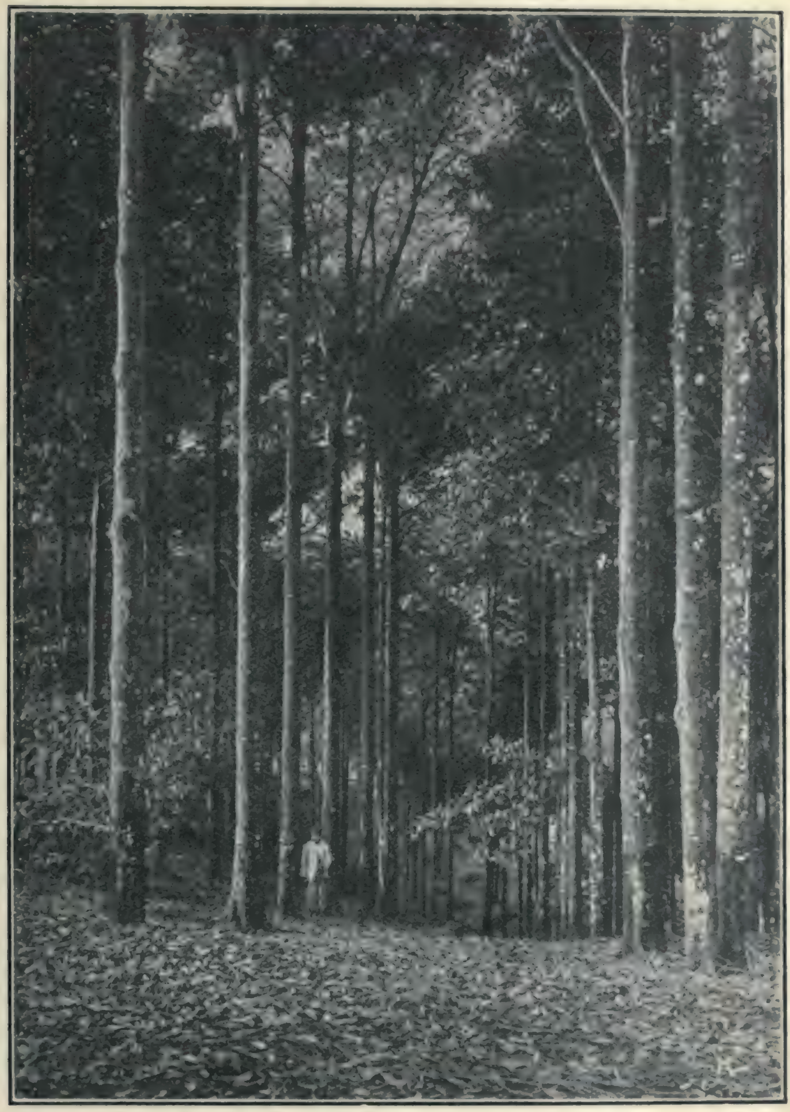


FIG. 116.—Netherlands Government gutta percha plantation in Java.

Buitenzorg, Mr. Cremer, then Dutch Minister of Colonies, whose attention had been drawn to the subject, was recommended to promote the cultivation of gutta percha trees on a larger scale than had until then taken place. The Minister acceded to this proposal, and in 1900 it was decided to establish a Government gutta percha plantation, with the carrying out of which the Director of the Botanical Gardens at Buitenzorg was entrusted. The cultivation on a large scale

would not have been practicable within a short time, if Treub and Burck had not previously adopted measures for the planting of seed trees, it being evident that no quantity of seed worth mentioning could be obtained from forest trees.[1] Dr. Burck had brought with him several seedlings from his journey in the Padang Highlands in 1883, and these were planted in the Agricultural Gardens at Buitenzorg. In 1856, through the intermediacy of Teysmann, a small garden of *Palaquim oblongifolium* and *borneense* was planted in the Residency Banjœmas. As the space, however, was limited, a somewhat larger plantation was, on the advice of Professor Treub, laid out in 1885 at Tjipetir, in the Residency Preanger Regencies, for which the seed was obtained from the first-mentioned garden. When, therefore, in 1900 it was decided to open up a large gutta percha plantation, there was no difficulty in obtaining seed, owing to the existence of a great number of seed-bearing trees in the small plantations already mentioned. If there was for a moment any doubt as to which place in Java was most suitable for the new plantation, the preference was speedily given to Tjipetir. Evidence had shown that gutta percha, *although not growing wild in any part of Java*, flourished there. Moreover, the opportunity was favourable, as there were about 5000 acres of forest ground available at Tjipetir. The immediate neighbourhood of the seed trees, the presence of cheap labour, and the nearness to a railway station and to Buitenzorg, were other considerations which influenced the decision come to.

The Government gutta percha plantation at Tjipetir.—This plantation is situated in the Residency Preanger Regencies, eight miles from the railway station Tjibadak, and seventeen miles from Wynkoops Bay, on the south coast of Java, at an elevation of about 1700 feet above the sea, on the spurs of the extinct volcano Salak. The plantation is divided into the following subdivisions: Pasir Kilang, Tjirawa, Tjipetir, and Panjindangan. The climate is healthy and pleasant, with a maximum temperature by day of 27°·4 C. and by night of 19°·7 C., while as regards moisture, it may be classed with those regions having an abundant rainfall. In the neighbourhood of the plantations are situated a number of flourishing tea estates. The cultivation of tea prospers here exceedingly. *Soil.*—The gardens are hilly, and, consequently, the composition of the soil varies in different places. On the summits of the hillocks, and in places which have formerly served as farm ground for the native cultivators, who took no measures to prevent washing away of the ground, it is less fertile than in those areas which were formerly covered by forest. The soil consists principally of a brown porous clay with about 9 per cent. of sand. The subsoil is also porous to a considerable depth, so that no drainage precautions have to be taken. In the rainy season it is easily worked, for which purpose the native hoe is exclusively used. No use is made of European farm implements, such as ploughs, harrows, rollers, spades, etc., they being too expensive and unsuitable. A great advantage lies in the capacity of the soil for retaining moisture, so that even in the event of a drought of two months there is still sufficient water in the ground, and it has not yet happened that the leaves of the trees have drooped owing to drought. *Method of cultivation.*—Although gutta percha trees in the forests originally grow in the shade, it is not necessary to cultivate them in this manner any more than it has been found necessary in the case of Para rubber trees, which, in the natural state, grow between other surrounding trees. On the summits of hillocks and other exposed situations it is desirable to give the young plants some shelter. This is possible by planting at the same time *dadap* (*Erythrina*) or other plants which are useful for green manuring, such as *Tephrosia*, *Indigofera* and other *Leguminoseœ.* In the beginning gutta-percha was planted at a distance of fully 12 feet by 12 feet. When more planting material was available, and it appeared that by closer planting the upkeep was cheaper, and that the plantation by the

[1] Bats are very fond of the ripe fruit, which they consume on the wing, so that it is very difficult to find seeds amongst the dense undergrowth of the virgin forest. Moreover, the greater part of the seeds lose their germinating power within four weeks after being plucked.

extraction of gutta percha from the leaves could more rapidly be brought to the stage of production, a closer method of planting was adopted, and the planting distance reduced to 4 to 6 feet square. As the gardens of Tjipetir are hilly, the rows of plants follow the slopes of the gardens, in the same manner as is usual in the cultivation of tea. Measures must be taken to prevent washing away of the ground by the abundant rains. Young plants in the beginning have to struggle against crickets and white ants; and at a later age leaf-eating caterpillars such as *Rhodoneura myrtæa Drury*, *Ophiusa serva Fabr.*, can cause a great deal of injury to the plants, the first-named being specially to be feared. Planted 4 feet apart in favourable gardens, the plants have closed up in their third year, and recourse must be had to thinning.

Planting material.—As already mentioned, the planting material is principally drawn from the seed-bearing trees planted by Dr. Burck at Tjipetir in 1886. In the beginning Dr. Burck planted *Pal. oblongifolium*, *Pal. gutta*, *Pal. borneense*, and *Pal. Treubii.* The planting material of these trees as regards *Pal. oblongifolium*, was obtained partly from plants collected by Dr. Burck in the Padang Highlands, and partly from the plantations in Banjœmas. The seeds of *Pal. gutta* and *Pal. borneense* came from the Botanical Gardens. The propagating of the last-named species was less rapid than that of *Pal. oblongifolium*, owing to want of planting material. The seed-bearing trees at Tjipetir therefore consist mostly of *Pal. oblongifolium.* When it appeared from a subsequent examination that the product of *Pal. Treubii* had to be ranked with the inferior kinds, and, moreover, that the nature of its leaf did not readily admit of the mechanical separation of the gutta percha therefrom, all *Treubii* trees were cut down shortly after the establishment of the plantations, to make certain that no hybridising could take place with the superior species. *Pal. gutta*, *Pal. oblongifolium*, and *Pal. borneense*, which possess a great similarity one with the other, all yield a superior product. On the Government gutta percha plantations these three species are now exclusively cultivated. At Tjipetir the gutta percha trees blossom about August, and the fruit ripens in February–March. Not all gutta percha trees blossom. From the 8596 trees older than fifteen years, 2360 bore fruit in 1906. Before the tenth year the quantity of fruit borne is unimportant. A single seven-year-old tree bore some fruit a short time ago. It must here be noted that a crop of seed cannot be looked for every year, as in some years the crop is a failure. The seeds soon lose their germinating power. If they are not planted within four weeks, then the majority have lost their germinating power. The seeds, which are as big as an almond, are planted in covered nursery beds at distances of 15 centimetres. The germination takes place within fourteen days. The seeds must be superficially planted, as the young stalk grows twisted if they are planted too deep. After nine or ten months the young plants are fit for transplanting. It is, however, better to transplant them when over a year old. When transplanting, the tap root and young stem are shortened. Propagating of gutta percha trees by means of cuttings or grafts is difficult, so that for planting on a large scale one is entirely dependent on seeds.[1]

The planting distance is, as already stated above, not everywhere alike. During the last three years the trees of several plantations have been planted at

[1] This seems in conflict with what Obach says in his Cantor Lectures:—"It has variously been asserted," says Obach, "that gutta trees cannot be reared from seeds. But I can assure you, on the high authority of Dr. Treub, that this mode of propagation is quite feasible, although the seeds do not keep their germinating power very long, and a more certain method is that technically known as marcottage, which consists in burying a branch of the tree in the ground, allowing it to take root, and afterwards separating it from the parent. According to information obtained for me from a Chinese gutta planter, cuttings from old trees can also be used for propagation, and it is best to insert them into a cocoanut to take root there and then transplant them. Young plants reared in this way can be bought at Penang and Batavia at 50 cents a piece. Saplings from the jungle where obtainable, or from plantations, are also suitable for transplanting, and they can now be bought in Malacca at a very low price. Dr. Treub finds young plants reared from *Marcottes* more vigorous than those from seeds. Grafting is declared to be impossible by Mr. Ridley, on account of the fungi and bacilli which attack the plant. M. Serrulaz took the whole stools from the forest and transferred them to a nursery."

a distance of 4 feet by 4 feet, while in the older gardens the distance is 12 feet by 12 feet. Where the gutta percha does not flourish, other kinds of trees are planted.

Obtaining the product.—As is already known, the gutta exists not only in the bark but also in the leaves. The bark contains about 5 per cent. gutta percha, of which about 3 per cent. is gutta,[1] and the fresh leaves[2] of the superior kinds contain about 10 per cent. gutta percha, of which about 5 per cent. is gutta, calculated on the basis of dry matter. Fresh bark contains about 65 per cent. water, and in the case of freshly plucked leaves this figure amounts to about 60 per cent. Young bark and young leaves contain a larger percentage of water. A portion of the latex is obtained in a very simple manner from the bark. For this purpose it is necessary to make an incision in the stem, and after a short time the latex exudes from the wound. To obtain as much product as possible from the stem, the natives first fell the tree and afterwards proceed with the real tapping. For this purpose they ring the stem at distances of a foot. The latex that exudes from the circular wounds is caught up in basins. A portion coagulates in the wounds, which is later on collected together with a scraper. The liquid latex is placed in a pan above a slow fire to coagulate, softened in warm water, and afterwards kneaded firmly together. The gutta percha which the leaves contain is not obtained in so simple a manner. At a comparatively early date people concerned themselves with the preparation of gutta percha from leaf. The first idea was to obtain the gutta percha from the leaves by extraction with chemical substances, such as toluol, benzine, etc., but no practical results were obtained by these methods, *as the gutta percha after being treated by these agencies undergoes a change which makes it unsuitable for the insulating of submarine cables.* Better results were however obtained from mechanical preparation. This method was first brought into use by a Frenchman named Arnaud. Later on it was improved and applied on a large scale by Ledeboer, who for that purpose established a large factory at Singapore. The method is in principle to grind the fresh leaves to a pulp, which is then boiled with water, after which the gutta-percha, which rises to the surface, is skimmed off. Dr. Tromp de Haas has also succeeded in obtaining gutta percha from old fallen leaves by mechanical means. The yield is in this case not so large as from fresh leaves.

The preparation from leaves has the following advantages :—1. In the case of cultivated trees, a commencement may be made with the obtaining of the product in the third and fourth year, whilst otherwise at least fifteen years must elapse before the stems can be tapped. 2. In this manner the largest yield per planted acre is obtained. 3. This method of collecting is the least injurious to the tree. It is intended to work the Government gutta percha plantation according to both systems, namely, by obtaining the product from the leaves, by mechanical process, and by obtaining the product from the stem. This is possible if, from the beginning, the trees are planted closely together. In the course of years a thinning out takes place in such a manner that at last a certain number of well developed trees remain standing, which must serve for the obtaining of the product from the stem. For this purpose they will not be felled but regularly tapped. From the leaves and young twigs, obtained from the thinning out, the gutta percha will, in the meantime, be extracted by mechanical process. In order to obtain an idea as to the probable results, the following leaf-production was obtained in an experimental plot at Tjipetir. From a three-year-old garden with trees planted

[1] The latex consists chiefly of water, gutta percha, salts, proteids, and some other substances. The proportion of gutta percha amounts to about 40 per cent. Gutta percha itself consists of a mixture, probably of some solid gutta hydrocarbides with different quantities of oxygenous compounds, to which the general name of resins has been given. Gutta is the most important ingredient, and the properties of gutta percha are for the most part dependent thereon. The produce from the stem of the best kinds contains about 85 per cent. gutta and about 15 per cent. resinous matter. Gutta-percha prepared mechanically from the leaves contains about 90 per cent. gutta and 10 per cent. resinous matter.

[2] The quantity of gutta and resinous matter in the leaves is not always the same. This is dependent on various factors, such as age of the leaf, of the tree, etc.

4 feet apart, from 0·88 acre 890 kilos. of fresh leaf was obtained by pruning and thinning out, and the following year 2744 kilos. After the thinning out there still remained 1320 trees per 0·88 acre. For the following years no particulars are yet known. From an experimental area measuring 0·35 acre, comprising 55 trees planted in 1888, the quantity of fallen leaf was weighed during two years. The average fall on leaf amounted per year to 1368 kilos., or about 25 kilos. per tree. Above figures must not be taken as a basis for the whole plantation, because the condition of the experimental plots is generally more favourable than that of the whole plantation, but they allow us to make a cautious estimate. Experiments regarding the tapping of the trees according to the native method, *i.e.* by felling the trees, gave the following results:—8 twenty-year-old trees yielded 1831 grammes gutta percha, or an average per tree of 0·228 kilo; 363 twenty-year-old trees tapped according to the herring-bone method yielded after three tappings (after the third incision no more juice exuded from the wounds), 30·048 kilos. gutta percha, or an average per tree of about 80 grammes; 25 nineteen-year-old trees tapped according to the same method yielded 1819 grammes gutta percha, or an average per tree of 73 grammes. In 1912 the plantation will be in full production as regards the crop of leaf. With the winning of product from the stem, a commencement cannot be made before 1915 as regards the gardens planted in 1900. The oldest trees will then be fifteen years old. The yearly yield from the stem products is estimated to be 11 kilos. dry gutta percha per acre for the whole of the Tjipetir plantation.

Gutta percha fat.—The seeds of the gutta percha tree contain a great amount of a vegetable fat of high melting-point, which can very well be used for several technical purposes. The seeds consist of about 85 per cent. kernels and about 15 per cent. husk (or shell). The composition of the fresh kernels is as follows:—Water, 45 per cent.; ash, 1·6 per cent.; proteids, 4·8 per cent.; fat, 32·5 per cent.; carbohydrates, 14 per cent.; fibre, 2·1 per cent. Based on water free substance—ash, 2·90 per cent.; proteids, 8·75 per cent.; fat, 59·09 per cent.; carbohydrates, 25·46 per cent.; fibre, 3·82 per cent. The melting-point of the fat is about 40° C., and it is thus solid at ordinary temperatures. It is composed of the following fats:—Stearine, 57·5 per cent.; oleine, 36·0 per cent.; palmitine, 6·5 per cent. To make an estimate of the future fat production is not easy, seeing that the fruit bearing of the trees is very irregular. In 1906, of 8596 gutta percha trees over ten years old, only 2360 bore fruit, which produced 3795 kilos. dry kernel, and this quantity, if worked to obtain the fat, would have yielded 1850 kilos. In 1918 all trees at Tjipetir will be ten years old. Supposing that the number of trees per acre averages 142, then the total number of trees would be 347,000. If we take the figures of the year 1906 as a basis, of the 347,000 trees only 27·4 per cent. nor fully 95,000 trees, would bear fruit, with a production of fully 150,000 kilos. dry kernels, out of which fully 74,000 kilos. fat could be extracted. In 1904 the value of 100 kilos. of this fat was estimated to be £2, 14s., a value higher than that of Chinese vegetable tallow (from Stillingia Sebifera).

CHAPTER III

METHODS OF COLLECTION — FELLING AND RINGING *VERSUS* TAPPING—EXTRACTION OF GUTTA PERCHA FROM LEAVES BY TOLUENE, ETC.

In Sumatra, wild gutta percha is got by felling the tree. When the trees are of colossal size, they are swollen at the base. This enlargement takes the form of vertical plates, and the wood-cutters are obliged to erect a scaffolding from which to fell them. Such giants are rare, and are only met with in forests where the natives have not yet penetrated regularly to secure the resin. The native collectors of gutta percha go to the forest generally in gangs of three to four, and as the producing trees are found in the densest parts of the virgin forest, and as the woods adjoining the *kampongs* (villages) have for a long time been denuded, the gutta percha searchers have to make a home for several days in the forest, and build a common hut for the purpose. They know, with marvellous skill, how to discover the gutta percha tree in the densest part; and if they have the slightest doubt in regard to the tree they want, the leaves of which they cannot discover under the vault of foliage which often overhangs it, a simple incision in the trunk causes a milky juice to run into their hands, the quality of which they can thus easily determine. Moreover, they can distinguish the species without risk or error by the trunk, by the thickness of the bark, and the greater or less hardness of the wood. If they find a tree which appears to them to be rather big to be exploited, they fell it with an axe, after which they "ring" it, *i.e.* trace semicircles on it by means of a hatchet 30 to 50 centimetres (say 12 to 20 inches) apart. In some localities, *e.g.* Borneo, before ringing the trunk, they prune or strip the fallen tree to the summit, so as to hinder the milky juice from spreading through the branches and leaves of the cyme. The juice collects with greater or less speed, according to the species, in the rings traced by the hatchet. Obach collected some figures as regards the quantity of solid gutta percha yielded by an adult tree. The data given are, he points out, very conflicting. Older writers like Oxley and Logan give as the average $13\frac{1}{3}$ lb. and $5\frac{1}{3}$ lb. for Singapore and Johor respectively, but later observers quote much smaller figures. Wray, for instance, obtained only 2 lb. 5 oz. of fairly clean gutta percha from a Taban merah at least a hundred years old, and 2 lb. 11 oz. from a Taban puteh. Burck obtained on an average only 11 oz. from adult trees in West Sumatra, and Serrulaz $13\frac{1}{2}$ oz. from a giant tree felled in Pahang by Dyaks. The yield evidently depends greatly upon the kind of tree, manner in which it is bled, the season, etc., the milky sap being said to run most freely directly after the rainy season is over. When the tree is wounded without first being felled, the latex flows much more tardily and sparingly and also coagulates quicker, the output is therefore notably smaller,—this being one of the reasons why the Malays still resort to the old method of cutting the trees down before bleeding them. Sherman (1907) says, "Trees of inferior grade have been found to give as high as 8 lb. Probably the best average obtainable is 3 lb. In the Tiruray district of Mindanao I secured 1 lb. of clean gutta percha from a tree 135 feet high and 5 feet 4 inches in circumference at the base. The work was carefully done by the natives. Taking a measured amount of the bark of this tree after no more gutta percha could be collected by the native method, and extracting all of the gutta

percha which it still contained, it was estimated that after collection there still remained $6\frac{1}{2}$ lb. of gutta percha. Taking into consideration the fact that had the tree not fallen in such a way as to leave almost all of the trunk propped high enough above the ground to allow the milk to be extracted from the bark on the underside, the amount extracted would undoubtedly have been much less, or, in other words, ten times more gutta percha would have been left to rot with the tree than was taken from it by the natives. Other investigators have secured figures as large as these, and some found that forty times more gutta percha was left behind than was secured by the careless collectors." The latices of the *Payena Lerii*, of the *Tuban derrian* and *tembaga* of Soupayang, does not coagulate immediately; but that of *Dichopsis oblongifolia* is thicker, easily gelantises, and condenses between the bark and the fibres of the wood. In regard to the *Dichopsis*, the searcher splits with his hatchet the bark of the open ring, and reduces it to a soft pulp, which stops leakage on the outside. Some say the native only regards as good gutta percha that which solidifies in his hand. That is a great error, and Burck affirms that the gutta percha searcher knows well that the species which yield a clear juice may furnish a very utilisable gutta. The collection of liquid gutta percha is made in certain localities with extreme carelessness; whilst the operator traces the rings at the base of the cyme, a considerable quantity of juice flows away. He does not take the trouble to collect this liquid in the bowls or in the receivers cut in the bark of the trees. Certain searchers pretend that the gutta percha which thus flows away is of inferior quality, and is only sold at a low price in commerce; it is too white, and they know that the red or brown colour is preferred. Others give no reason for their negligence. The tree having been ringed up to its summit, it is necessary to collect the juice, which immediately shows itself in the rings or depressions.

Everything in the depression—as much bark as solidified juice—is drawn out with an iron scraper, and packed into a bag made from the matweed. When the rings have been scraped, the task is regarded as finished, and they go on to repeat the same operation on another tree. The milky juice often continues to flow into the rings rather abundantly; it is, however, neglected, and the tree is wholly abandoned. The incisions are only made on the upper half of the fallen tree. The other, the lower half, touching the soil, remains intact; it is impossible to turn this half to incise it, as it would entail too much manual labour, too many workmen, and the situation of the tree, in the middle of the forest, on uneven ground, presents numerous insurmountable difficulties. The tree, half freed of its gutta percha, remains neglected in the wood, yet that tree yields a workable wood and excellent building timber. In other localities these same trees are felled, to be split into boards or planks, without bothering to collect the gutta percha This method of working shows incredible improvidence. Each giant tree felled brings with it a certain number of others. It is sometimes necessary to previously fell those which surround it, and which are bound to it by climbers which would hinder its fall. The consequences of such a destruction of guttiferous trees were easily foreseen, and have been more acutely felt every year for a long period.

As the adult trees are already felled where it has been possible to penetrate, the natives are forced to content themselves by exploiting the young trees, which only yield an insignificant quantity of latex. It is said that a gutta percha searcher does not look upon a *Dichopsis* as worth exploiting until the tree reaches the size of a cocoa-nut tree, about 1 metre (3·28 feet) in circumference. But now it rarely happens that trees of this size are encountered, and it is therefore necessary to fall back upon the young plants. In the forests a considerable quantity of large guttiferous trees may still be found yielding a product of inferior quality, not exploited formerly. These have only commenced to be exploited within the last twenty-five years, as the better sorts became more and more rare, and the demand grew from day to day. "It is fortunate that only the full-grown trees contain enough gutta percha to repay the work of felling and wringing, otherwise the complete extermination of the gutta forest would only be a matter of a year or so. On the

other hand, the felling of all the trees old enough to bear seed works to the same end with a longer limit."—Sherman, *loc. cit.* Obach gives the following account of how the latex is obtained:—In order to get at the latex, it is therefore necessary to cut through the bark and cause it to exude. The practice of the Malay getah-collector is invariably to fell the tree, chop off the branches, and ring the bark at distances of 12 to 18 inches all along the trunk. The milky sap soon fills the grooves cut into the bark, and with the better kinds of trees quickly coagulates; it is then scraped off with the point of a knife. In the case of inferior trees, the latex requires a much longer time to curdle, and has to be collected in a receptacle of some sort, a cocoa-nut shell or the spathe of a palm, for instance, placed under the trunk. The latex is then taken to the huts and gently boiled either by itself or with the addition of water. The material obtained without water is called a *goolie*, the other a *gutta*; but the two kinds are mostly mixed together. The *goolie* is more compact than the *gutta*, and it has a dough-like smell. For felling the trees the Malays use a small axe, called a *billiong*; it has a chisel-like edge. The gutta percha which Leon Brasse and Seligmann Lui saw collected undergoes a preparation which varies with the species. The milky juices—such as that of the *Payena*—are carried to the hut in the liquid state, whilst that of the *Dichopsis*, which is thicker, is of necessity mixed with woody fragments as soon as it issues from the tree. On the way the juice further condenses, the operator takes out the largest pieces of débris by hand, and throws the mass into a pot filled with hot water. The gutta percha softens therein and becomes plastic, and is easily transformed into a compact mass. Good qualities do not stick to the fingers. The plastic mass is reduced to as thin and flat a band as possible, and the remainder of the ligneous corpuscles, however thin, are removed from the surface of the band by hot water, or by rubbing with the hand, or in any other way. Generally, the same operation is repeated a second time; the gutta, again softened, is kneaded, drawn into sheets, washed and rubbed, and finally rolled on itself into lumps or pieces of different size and shape. Hence the foliated appearance seen in the body of the cakes. Twice purified gutta percha is distinguished by its superior quality from once purified. But as put on the market it is far from being pure, and is still mixed with an enormous quantity of woody particles, which cannot be removed without undergoing various tedious operations described in the sequel. In Sumatra, far from purifying the gutta percha previously, crushed bark is added to it by the handful. Gutta percha changes colour in the course of these operations. As it issues from the tree it is always white. Boiling with the débris of the bark and the wood causes it to contract a deeper tint and diversely coloured hues; and if the gutta of the *Payena* takes a yellowish tint in contact with air, the colour of the *Dichopsis* is entirely due to the colouring matter absorbed on boiling. Certain writers assert that collectors boil the gutta percha with a tinctorial substance, to impart to it the colour sought after in commerce. There is no need for such trouble, at least in Sumatra, where the gutta is red, because it is not possible for it to be otherwise when it comes from a *Dichopsis*, as it is always mixed with fragments of bark sufficient to colour it. It is rare that such gutta percha is put on the market pure. *Balam-tembaga*, *balam bringin* consist for the greater part of a mixture of several kinds. This mixing is so general that it is altogether impossible to procure pure samples free from admixture from the native merchant. The most successful mixtures often bear the name of *balam-tembaga*, even when the juice of *Dichopsis oblongifolium* is altogether absent. Every mixture regarded as a falsification, if we look at the matter from a purely scientific point of view, cannot be regarded as such unless done on purpose and with a view to a premeditated fraud. The gutta percha searchers who have got a certain quantity of superior quality *balam* soon see that they have not enough to sell it profitably. They go in quest of a tree capable of yielding a substance of the same kind, and, as the search would take too much time, they have recourse to the first tree they meet, until they have got as much as they want. Returned into their *kampong*, they have in hand several kinds of gum resins, but

too little of each kind to sell it separately; it is then they make the mixtures already described. Experience tells the kinds which would spoil the mixture, and they take good care not to use them to their own detriment.

Yield of gutta percha, effect of age, size, etc., from a Dichopsis.—According to Burck's calculations, 250 grammes (about ½ lb.) of completely purified gum is the amount produced by a *Dichopsis oblongifolium* of 65 feet in height, with trunk 24 inches in circumference at a man's height, whilst a tree of the same species of only 16 inches in circumference only yielded 160 grammes (about 5 oz.). But a *Dichopsis* of 16 inches in circumference is far from being in the adult stage; its circumference would have to be doubled before it would be of age to bear flowers and fruit. Now a tree of 16 inches is very rare in our days. However that may be, it may be taken for granted that a *Dichopsis* of twenty-six years of age yields 300 grammes (rather over 10 oz.). The figures given by Serrulaz, which certainly refer to the *Dichopsis*, are very approximate to the above. According to that writer, a four-year-old tree does not as yet yield latex; from fifteen to twenty years it gives 90 to 110 grammes (say 3 to 4 oz.). At thirty it may yield 250 to 260 grammes (say 8¾ to 9 oz.). When fully developed, its production might amount to 500 grammes (say 17½ oz.) (exceptional maximum reached). Finally, in declining old age its production is reduced to nil.

It has often been asked if there were any absolute necessity for felling the trees, and if it would not suffice to incise the trunk to obtain gutta percha. The native Malay knows very well that this more rational method, applied to the same tree for a determined series of years, will in that way yield each time a certain quantity of gutta percha; but it is difficult to wrest from him the idea that this method would considerably diminish the annual production, and would give but a very insufficient remuneration for his efforts. In his work of destruction he thinks of nothing but his immediate tangible interests, without the least care for the future. Nothing appeals to him but the greater or less degree of trouble inherent to his work. If climbing the tree and incising the bark appeared to him more easy than felling, then he would incise, as he does with the indiarubber tree. As to the gutta, he is convinced that felling will give him less trouble than incision, and he does not see why he should incise for a production which he regards as insignificant. Yet incision without felling yields at least one-half, if not two-thirds, of the amount yielded by felling; for do not let us forget that by felling only half of the available gutta percha is obtained, since the substance is only extracted frcm that part of the tree which does not repose on the ground. Moreover, a partial flow of the milky juice causes no injury to the vegetative vigour of the tree, and Burck tapped four trees of the same species, and it did not even hinder them from flowering six months afterwards,—a sure proof of the harmless nature of upright tapping. The incision of living trees is therefore not only possible but more advantageous, and yields a continuous supply without drying up the sources of the precious hydrocarbide so rapidly as felling.

Extraction of gutta in Borneo.—Leys, Consul-General of the British possessions in North Borneo, describes the process of collection followed in the north-west of that island, *i.e.* in Sarawak, in Portianak, Labuan, etc. etc. The different sorts are the products of different trees, but the pure red gutta percha of Borneo is the product of a *Dichopsis*. Other species yield inferior quality latex, which are mixed by the natives with good gutta percha. The red quality is obtained from trees of 100 to 150 feet, which grow in old jungles on the hill sides. The raw product is extracted as follows:—When the searchers have found a tree old enough to be profitably exploited, *i.e.* having a circumference of 12 inches at a man's height, they fell it, cut off the top, and ring the bark at distances of about a foot. The latex flows for two or three days; it is collected in any kind of a vessel, such as leaves or a split cocoanut; it is then boiled in a pot for half an hour with a small quantity of water, which hinders it from hardening on the outside later on by exposure to the air, and thus be so far deteriorated as to be of no commercial value. It is difficult to estimate the yield of a tree, because the

quantity varies with its size and the season; the flow of the latex reaches its maximum when the foliage is fully developed; but the yield varies greatly with the age. A small tree generally yields 33 lb., whilst a larger tree may yield as much as 100 lb. Another *Dichopsis*[1] yields a white inferior gum resin. It is smaller, and only attains a height of 50 to 60 feet. Its foliage differs slightly, and barely produces but 12 to 13 kilos. ($26\frac{1}{4}$ to $28\frac{1}{2}$ lb.) of gutta percha.[2]

Dr. Sherman, jun., of the U.S.A. Government Laboratories, Manilla, gives the following description of both the mechanical and the chemical process of extracting gutta percha from bark and leaves:—(1) Mechanical: The leaf is ground to a powder and then treated in hot water so that the gutta percha is gradually worked into a compact mass, while the pulp of the leaf is washed away. Up to the present (1903) the process has not been perfected, for though the gutta percha contained is of good quality, the percentage of recovery is smaller than it should be. The largest factory of this kind is being erècted near Singapore, and it proposes to use the leaves from a plantation of 100,000 trees on the island of Rhio, some five hours from Singapore. (2) The chemical process is carried out in the same lines as the mechanical one so far as the grinding of the leaves is concerned. The powder is then extracted with solvents, and the dissolved gutta percha recovered either through precipitation or through evaporation of the solvent. The details of the process, as well as the solvents used, are kept secret, and no patents for this or the mechanical process have been taken out (*sic*). The largest factory producing gutta percha for the market is located at Sarawak, North Borneo, and is very advantageously situated as regards securing leaves from the surrounding gutta percha forests. It has been claimed, however, that the factory defeated its avowed object of preventing the destruction of the trees, for the native collectors employed would never risk their lives trying to collect leaves from forest trees over 100 feet high when they could gather them much easier by felling the tree and collecting a goodly amount of gutta percha in addition. It thus appears that the supply of leaves must come from a plantation where supervision can be exercised. The plan of felling the gutta percha trees of the forest and securing all of the material from the bark and leaves is worthy of serious consideration. In the first place, the trees are surely doomed as long as present conditions obtain. If the native can sell the entire bark and leaves for more than he could get for the gutta percha which he could extract, he will be tempted to bring them in. A second inducement for this method is the fact that many gutta percha trees cut down even years previously have still much perfectly sound gutta percha in the rotting bark which could also be secured. The process of recovering the substance from the bark is practically the same as from the leaves, and about the same per cent. is found there as well. With a yield of 10 to 15 times the present amount recovered from each tree, the gutta percha market would be relieved at once and the extermination of the trees put off many years, long enough at any rate to allow plantation trees to take their place.

A large amount of work has been done in this laboratory with the purpose of finding a practical method for extracting the gutta percha from the bark and leaves of the gutta percha trees. The process calls for a solvent for the gutta percha which will dissolve it easily, can be recovered and again used, and above all has no deleterious effects on the substance.

The result of the experimentation led to a modification of the Obach hardening method for gutta percha. The process consists in extracting the gutta percha bark and leaves by means of hot gasoline, the apparatus being provided with reflux condensers. While the gutta percha has entirely dissolved, the solution is allowed to stand until all of the dirt and most of the colouring matter has settled. The clear supernatant liquid is then poured off and cooled to 10° or 15° F. below freezing. The gutta, with a small amount of resin, is thereby precipitated, and can be filtered off through cloth bags and dried. The resulting gutta can be further purified by redissolving in distilled gasoline and reprecipitating.

[1] *D. Macrophylla.* [2] 20 catties, $26\frac{1}{2}$ lb. per tree. These yields seem abnormally high.

The filtrate containing the dissolved resins is redistilled and the recovered gasoline used for effecting further solution of gutta percha, thus making the process continuous.

The gutta so secured, on being warmed, can be pressed into any desired form for experimentation. The gutta used in the above experiments was so prepared, and the results of the physical and chemical tests showed it to be unaffected by the process to any appreciable extent. A year's exposure to laboratory fumes has not changed the substance in any way.

It is to be noted that the process gives practically pure gutta and not gutta percha, the resins remaining dissolved in the gasoline. This is in itself a great advantage, as the gutta could be used directly for bringing up the percentage in inferior grades of gutta percha, and so make them suitable for cable insulation. The commercial value of this gutta has not been determined, but should be rated at about $600 Mexican per picul, judging from the price of the best gutta percha. In this way three piculs of Philippine gutta percha at $210 Mexican will produce 1 picul of pure gutta valued at $600 Mexican, or a gain of $390 for every 3 piculs of gutta percha (or the equivalent in bark and leaves) handled.

Extraction of gutta in the Philippines.—Sherman, from whom we have already quoted, gives the following interesting account:—The method, which is still in vogue from the westernmost part of Sumatra to the easternmost point of Mindanao, is, with various minor modifications, practically as follows:—The tree is first cut down and the larger branches at once lopped off, the collectors say, to prevent the gutta percha milk from flowing back into the small branches and leaves. As has been previously stated, the milk or latex is contained in the inner layers of the bark and leaves, in small capillary tubes or ducts. (See Fig. 14.) To open these so as to permit the maximum amount of the milk to escape, the natives cut rings in the bark about 2 feet apart along the entire length of the trunk. The milk as it flows out is collected in gourds, cocoanut shells, large leaves, or in some districts in the chopped-up bark itself, which is left adhering to the tree for the purpose of acting as a sort of sponge. After one or two hours, when the milk has ceased to flow, the contents of the receptacles are united and boiled over a fire for the purpose of finishing the partial coagulation. The warm, soft mass is then worked with cold water until a considerable amount of the liquid is mechanically enclosed. To further increase the weight, chopped bark, stones, etc., are added, and the whole mass worked into the required shape with most of the dirt on the inside.

The gutta percha gathered in this way well repays the amount of work expended. The two vital defects of the method are:—(1) The method is very wasteful, the yield from each tree being a small proportion to the total amount. What this per cent. is has been investigated by scientists with the result that the figures differ widely. Remembering that the gutta percha milk is contained in capillary ducts and tubes, it will be seen that a considerable amount cannot flow out on account of capillary attraction, no matter how much cutting is done. It very seldom happens also that a tree falls in such a way that all its trunk is exposed so as to admit of ringing on all sides. As a general thing, from one-third to one-half of it is inaccessible to the process of ringing, and all the milk within this portion is consequently lost. Even the larger limbs are not deemed worth ringing, and consequently all the milk in them and in the leaves also goes to waste; to this must be added the considerable quantity spilled on the ground through carelessness and lack of enough receptacles for every cut or bruise from which the milk flows. The method employed to find what percentage of gutta percha has been removed from a tree by the native collectors, was to determine the per cent. of gutta percha remaining in a given area of the bark, multiplying this by the total bark area of the tree, and adding 15 per cent. of this amount for that contained in the bark of the branches and in the leaves.

Marketing.—Having been collected and put in marketable shape, the gutta percha is carried in baskets on the backs of the collectors to the nearest waterway,

and thence by boat to the most accessible town, where, applying the description to the Philippines, it is exchanged for barter to some Moro, Chinese, or Filipino merchant (commerciante) living there for the purpose of dealing in all kinds of native products. From here it is shipped to one of the ports doing an export trade with Borneo and Singapore. The entire gutta percha trade is practically in the hands of the Chinese in the latter city, and they guard the secrets of boiling, working over, mixing, adulterating, and colouring the gutta percha for European markets most zealously. All who have tried to investigate their methods agree that there is no connection between the various grades and the different tree species, and that pure gutta percha from the species *Palaquium gutta* is no longer found on the market unmixed with inferior grades.

Strangely enough, Sherman was unable to find in Singapore any statistics regarding the importation of Philippine gutta percha. The Chinese dealers denied receiving any, and beyond a few piculs noted in the annual report statistics no mention of it was found anywhere. He afterwards ascertained that the gutta percha first goes to Sandakan and Labuan, in British North Borneo, and is there transhipped to Singapore, entering as North Borneo gutta percha.

Unfortunately the amount collected for exportation cannot be given with any degree of accuracy, as the export statistics include gutta percha with all other gums. It is known, however, that the amount reaches into tens of thousands of pounds.

Balata.—Finally, *Balata* is obtained by condensation of the milky juice, but in order to extract it from the tree it is not sufficient, as in the case of indiarubber, to make a few incisions in the bark. The liquid is thicker, and coagulates so soon that the incisions would become obstructed in a very short time.[1] In the beginning, collectors felled the trees at their feet (close to the ground) and then raised them afterwards on to supports, so as to allow the vessels to be placed underneath for collecting the milk as it ran from deep cuts barely a foot apart. In this way each incision gradually allowed the milk to exude, and thus be collected. By this barbarous method a tree of average height yielded 3 to 6 kilos. of balata (6½ to 13 lb.). At the present time, *portable presses* are used in which the bark is submitted to great pressure. A press yields 9 to 13 litres of juice hourly, which produces 2 to 3 kilos. (say 4½ to 6½ lb.) of dry balata. There are large trees encountered towards Maturin which yield by this process several quintaux of balata. This *destructive system* is pursued at the present time, and with great profits. It will very soon destroy, if continued, all the balata trees of Maturin, where they are, however, very numerous. The *Purvio* is met with in British Guiana, and is wrought in a more sensible way, from the point of view of the preservation of the producing tree. *Some longitudinal incisions* are made on the trunk, between which the bark is removed, but leaving from point to point fibres of this bark, which serve as points of support to the new bark, gradually covering that which was torn off. The best process consists in removing, and allowing to remain, rectangles of bark of equal surface. The bark is afterwards pressed. A tree of average size gives by this method of collecting about 2 lb. of balata, but the process may be repeated indefinitely by removing annually the portions of the bark which were not touched the preceding year. The quantity of milk is greater during the rainy season; the coagulation is also slower at that time. The native collectors say the extraction gives a better yield during the waxing of the moon, an observation or prejudice which guides many European harvests. The milk of the *Purvio* is reddish, with an astringent taste. It is collected in wooden vessels. Iron vessels impart a blackish colour, which diminishes the commercial value of the dry product. The balata milk is sold as it is, fetching about one dollar per gallon, or it is evaporated

[1] According to Obach, it was formerly the custom in Jamaica to fell the trees and ring the bark as in the case of true gutta trees; but this method has been abandoned, and the trunk simply tapped, which is quite practicable, as the balata milk is much more liquid than that of the gutta percha tree. In Surinam the trees are likewise tapped.—Tr.

to obtain the pinkish or greyish coloured solid balata. A gallon of milk yields about 4 lb. of dry balata. A bleeder of average skill obtains about 4 gallons and a half, and a very successful one as much as 10 gallons per day thus, realising over 3 oz. (Obach). Each gutta percha tree thus yields absolutely different qualities and quantities, according to species, age, and geographical and climatological situation. This explains the apparent contradictions in the writings of Serrulaz, Burck, and Brasse, etc. In any case, the question of the dearth of gutta percha is a vital one, which incessantly and acutely occupies public attention, not only in the industrial but also in the administrative world.

The toluene extraction of leaves, etc.—From this point of view, a research of M. Jungfleisch, Professor *au Conservatoire National des Arts-et-Métiers*, published in the *Bulletin de la Société d'encouragement* (October 1892, p. 709) is of historical interest. The memoir commences by making allusion to the communication made by Dr. Serrulaz to the same Society, in its session of the 8th April 1892, in giving an account of the expeditions with which he was entrusted, in Malasia, to seek the plant capable of yielding the best gutta percha. Serrulaz there, for the first time, said a few words regarding a new method of extracting that substance—a method in which he took pleasure in ascribing to Professor Jungfleisch, although he had himself taken an important part in it. Jungfleisch had for a long time studied the proximate principles of which the mixture called gutta percha is constituted. With the assistance of one of his students, M. Damoiseau, he obtained them all in a crystalline state, *i.e.* under a form which would hardly foretell the so highly accentuated plasticity of the mixture. However, the irregular composition of the commercial raw material, certain differences found between the properties of the principles obtained from different guttas, the dread of not being able to reproduce with certainty with a second gutta the results obtained from the first, had adjourned the publication of the common results. The desire of pursuing these researches upon a product of certain origin had necessarily drawn the attention of M. Jungfleisch to the results obtained by the French expeditions, which were then at work to throw light on the question of the origin of gutta percha, and in particular on the questions dealt with by the expeditions of Seligmann Lui and Serrulaz. Seligmann explained to him all the difficulties in procuring, even in small quantity, a gutta of perfectly authentic origin from a well-defined plant. He was thus glad to get from Serrulaz the information collected by him during his first expeditions. Jungfleisch had hopes of resuming his researches on a sample of gutta percha of certain origin, and so bring his contingent of light to bear on so obscure a question naturally, but rendered more so by those interested. Information as to gutta plants was quite vague and contradictory. In any case the Malay method of working was essentially a method of laying waste, and was to cause the forests to disappear in the near future, and along therewith the raw material indispensable to the electric industry. The Malays can only work upon trees of twenty-eight to thirty years old, or upon shoots of fourteen to fifteen years, and the felling of a thirty-year-old tree only furnishes them with but 265 grammes (say 9½ oz.) of raw gutta, often charged with nearly half its weight of foreign matter of no use, and often injurious for manufacturing purposes. Operating with more care and patience than the Malays, Serrulaz was only able to extract from a thirty-year-old tree 220 grammes (say 8 oz.) of purer gutta, it is true, and he has seen a tree of 1·20 metre (say 4 feet) in diameter operated on which only gave 328 grammes (say 11¼ oz.) of raw product.

Such primitive and poorly productive processes are peculiarly astonishing when viewed alongside the enormous consumption. In 1884, for example, M. N. P. Trevenen, after summing up the quantities of good and bad gutta percha exported from the Malay ports, got a total of 52,067 piculs (say 3,144,147 metric tons), which, according to the preceding data, would correspond with the destruction of more than 12,000,000 of thirty-year-old guttiferous trees. All these trees do not yield prime quality gutta percha, and the Malays add to the substance

collected vegetable and even mineral matter of the most different kinds. Whilst the Chinese intermediary, under the pretext of imparting a commercial shape to the substance, works the product with so much skill as to singularly increase the weight. Again, the European merchant *purifies* the goods by reboiling them, a process which results in a fresh multiplication of cakes. But, granting with Jungfleisch the coefficient of growth which these operations bring about, yet the consumption of trees is still enormous, and so much out of proportion that the precious plant is bound to disappear rapidly.

The *production* thus tends to *diminish* whilst *the demand increases* daily, and on every hand the great European States are driven to safeguard such an important interest by seeking a remedy for the evil in acclimatisation. The possible results of forest culture experiments of this kind undertaken 20,000 kilometres from Europe, on a necessarily gigantic scale if they are to be sufficient, have already been discussed, and the cause of the poor results obtained up to now is well understood.

Discovery of gutta percha in the leaves of the tree.—These difficulties led Jungfleisch to doubt the efficacy of the method, and to try if the question could not be regarded from another point of view. The examination by M. Serrulaz of small samples in 1888 demonstrated the presence of gutta in all parts of the plant. The organs other than the trunk contained gutta in quantities which was thought to be very superior to that which the trunk itself yielded in such minimum quantities to the Malays. May not the coagulable matter of the latex accumulate in some organ of the plant where it would be possible to seek it by more delicate methods than those of the Malays? If perchance these organs were those which may be separated from the plant without compromising its life, the question would have made a great advance. The unpublished researches formerly made, in fact, left no room for doubting the possibility of finding solvents for extracting the gutta from the organs in question, and to extract it alone. Serrulaz, then about to start for Indo-China, undertook to verify several of numerous hypotheses included in a programme of experiments performed in this line of ideas, and to despatch to France samples collected in determinate conditions, so as to permit of the necessary experiments being executed. Omitting all preliminary groping in the dark, and suppositions shown to be incorrect, the following facts have been established :—

The solvents by which gutta percha may be extracted from living cells are numerous. Up to now toluene seems the best. It dissolves the three principles of which the resin is composed, and except a little chlorophyll, does not appreciably dissolve the other substances which accompany it. Comparative experiments were made—

(1) On air-dried leaves, *i.e.* which had dried by exposure to oxidation by the air; (2) on fresh leaves brought home in antiseptic water, then dried on arrival; (3) on dried buds stripped of leaves; (4) on two-year-old wood, dried and stripped of leaves. Contrary to expectation, each of these parts of the plant yielded gutta in almost constant but always considerable quantities. This first result enabled a favourable issue to be predicted. He immediately fixed his attention on the part of the plant which could be most advantageously treated. By detaching the leaves which the plant constantly renews, and which it would not itself be slow in eliminating, the injury to the development of the plant is reduced to a minimum. The method of extraction, moreover, is very simple. The pulverised substance is exhausted by digestion at 100° C. (212° F.), and finally, by displacement with a solvent, *e.g.* toluene, a solution of gutta percha is obtained, coloured green by a little chlorophyll. The direct evaporation of the solvent not being practicable without injuring the product, it is distilled off in a current of low-pressure steam, *i.e.* at 100° C. (212° F.) at the maximum. One volume of water vaporised in this way carries over four volumes of toluene. The gutta percha remains. The whole of the toluene is expelled by prolonging the action of steam on the agitated mass kept at 100° C. (212° F.). The yields were above

all expectations, and oscillated between 9 and 10½ per cent., according to the parts of the plant treated, as shown in the following Table :—

TABLE XCII.—PERCENTAGE OF GUTTA PERCHA EXTRACTED FROM THE VARIOUS ORGANS OF THE TREE BY TOLUENE. (JUNGFLEISCH).

Quantity in Grammes.	Organ of Plant.	Gutta Percha extracted in Grammes.	Percentage of Gutta Percha extracted.
2000	Old wood.	200	10
2000	...	183	9·15
1000	Dry buds.	102	10·20
2000	...	211	10·50
2000	Dry leaves.	204	10·02
500	Incompletely dried leaves.	453	9·06
200	Leaves received in water.	21	10·05
200	...	18	9

But might not these high yields be due to admixture of the gutta with some vegetable principle extracted by the solvent? The greenish appearance of the product would appear to give force to this objection, Malay gutta percha being red. In reality, gutta percha, almost naturally colourless, is coloured, in the first case, by traces of chlorophyll, which may be removed by appropriate solvents, and, in the second, by the débris of bark and by peculiar vegetable principles, from which the substance, extracted by solvents, is altogether free. The capital point is, that all competent persons, merchants or manufacturers, who have examined the gutta percha yielded by the new process, have been unanimous in recognising it as quite superior, and to liken it to the best sorts which commerce no longer supplies to industry, to those of which the electrical trade regret more and more the increasing rarity. It is evident that more important quantities should be made, so that the research be followed under conditions adapted to decide upon certain particular points. But the use of solvents will lend itself, if used judiciously, not only to the extraction of gutta percha, but also to its industrial treatment, and even to its purification. M. Jungfleisch placed before the members of the Society a series of samples obtained by the solvent process. Contrary to what might have been feared from the extreme tendency to oxidation of gutta carbide, the leaves, although they came largely exposed to the action of renewed air, yielded a product of very good quality. We can therefore now imagine an exploitation of the *Isonandra* which survive in Malasia, based on the harvesting of the leaves, on the importation into Europe of dried leaves, and their treatment with solvents. The very special character of these leaves would protect manufacturers from any adulteration, and would ensure to them the production of an excellent quality gutta. Moreover, if it were a question of producing leaves or thin branches, the proximity of the harvest would encourage the cultivators of the extreme East to sacrifices the remuneration for which would not be delayed. Under these conditions, it is justifiable to hope much more from private initiative than from the perseverance and foresight, in reality very great, which were demanded of European States. In the meantime we may hope to see the actual method of exploitation more or less quickly stopped. The Malays will sell leaves as easy to collect as the gutta is difficult to extract. Thus a thirty-year-old tree, like those taken as examples, bears, according to observations made by M. Serrulaz, from 25 to 30 kilos. (say 55 to 66 lb.) of green leaves, say about 11 kilos. (say 24 lb.) of dry leaves, which would yield by the new method 1000 to 1100 grammes (say 2⅕ to 2½ lb.) of gutta, whilst the fallen tree would yield at the most 365 grammes (say 13 oz.). Moreover, in the Malay method there is left with the leaves and small branches, on the soil of the forest, a quantity of gutta

equal to several times that collected from the trunk. The Malays will understand soon enough, without doubt, that the collection of the leaves practised in several seasons of the year ought to bring them in much more than the felling—always laborious work—of large-sized trees. To continue the same example, it will suffice for a thirty-year-old tree to give them each year 7 kilos. (say 15½ lb.) of fresh leaves, which appears little, to bring them in as much continuously as its wholesale destruction will do once. Trees of all ages and all sizes, now of no immediate use, would, moreover, be capable of profitable exploitation. The complete transformation of the actual method of obtaining gutta percha seems therefore capable of shortly ensuring the supply of this interesting substance to European industry. It leads us to hope, moreover, that the future will be provided for by the private initiative of planters—an initiative to which we seem justified in promising very quick returns.

Summary of solvent processes for extracting gutta from leaves—1. *Rigole's CS_2 process* (British Patent, 4252; 3rd March 1892.—This apparatus resembles Dreschel's form of Payen's percolator. Pounded leaves are put into an upper vessel *A*, communicating by pipe *a* with an inferior vessel *B*, in which CS_2 is boiled, by heat of a water bath *D*; the vapours, which pass through *a*, are condensed in *C* (the top part of *A*), and flow back, charged with gutta, into the boiler *B*. After exhaustion of the leaves, steam is passed into *A*, and the solution in *B* is distilled off into a condenser. The gutta percha remains in the boiler, floating on the water condensed from the steam. 2. *Serrulaz's toluene process* uses a jacketed digester, with agitator *A*; runs toluene into upper vessel *B*, heated by external steam, and then suddenly discharges hot toluene on leaves by syphon. When solvent has done its work it is drawn off into retort, from which it is distilled (British Patent, 11,166; 14th June 1892); or the gutta may be precipitated by acetone (British Patent, 654; 9th Jan. 1896). 3. In *Ramsay's process* toluene as a solvent is replaced by rosin oil (British Patent, 17,936; 30th July 1897. Patent lapsed; non-payment of first renewal fee). 4. *Obach* takes advantage of solubility of gutta in boiling light petroleum to re-precipitate it by cooling below 60° F. His plant differs in no essential point from ordinary oil extraction plant. He uses a battery of two extractors, and works them alternately (British Patent, 19,046; 28th Aug. 1896). The density of gutta percha from leaves with $\frac{G}{R} = 5{\cdot}19$ is 0·9625 (Obach). Extraction by solvents brings injurious matter in its train and thus impairs durability of gutta, especially its resistance to air and light, and seems likely to be abandoned in favour of mechanical extraction.

CHAPTER IV

CLASSIFICATION OF THE DIFFERENT SPECIES OF COMMERCIAL GUTTA PERCHA

It is more especially in this section that recourse has to be made to the interesting work of L. Brasse. Understanding how difficult it is in the present state of our knowledge to proceed in a really scientific manner, persuaded moreover that the superannuated terms of Macassar, Singapore, Java, Sumatra, and Borneo gutta convey absolutely nothing to the mind, and that they are more apt to lead astray than to enlighten the opinion of any one who wishes to get an idea of the value of a gutta percha from these denominations, Brasse takes each of the species and studies its probable origin, the form under which it comes on the international markets, examines its appearance, the section, the nature and amount of foreign matter which it contains, its industrial properties, such as its sensitiveness, its hardness, its greater or less facility of cooling, the quality of the thread obtained. Again, he determines the ratio of the *gutta* to the resin in each species examined, and finally its specific resistance in megohms-centimetres. The percentage of impurities refers in his work to the industrial washing.

Ratio of gutta to resin.—He determined the ratio of the gutta percha to the resins in the following way :—Taking about 5 grammes which had been industrially washed, he dissolved them in benzine on the water bath, so as to get a solution of 200 c.c. He drew off 50 c.c. after filtration, and poured them in drop by drop into 100 c.c. of boiling absolute alcohol. The pure *gutta* is precipitated, whilst the resinous substances (*albane* and *fluavile*) remain in solution. He filters through tared filters, washes with absolute alcohol, and dries at 110° C. (230° F.) in a current of dry carbonic acid, and he thus obtains the weight of pure *gutta*. Another 50 c.c. of the liquid is evaporated and dried at 110° C. (230° F.) in a current of dry carbonic acid, and the difference between the two weighings gives the weight of the resinous substances. The *specific resistance* is calculated from a resistance test made on a wire insulated with the gutta percha to be tested. This work done on the whole series of known varieties is a model of its kind ; and if it be here condensed into one Table it is not in order to assume the paternity, but rather to facilitate for the reader the rapid understanding of the work, and to enable him by simple inspection of the Table to make any comparative researches which may be necessary. Brasse had no intention of giving an idea of the constitution of the gutta percha market. Many sortings of the commercial varieties were necessary before he could reunite these types. The information as to the origin was furnished to him by importers well versed in gutta percha, and by Singapore merchants. All types which, though constituting a homogeneous whole, yet in virtue of all their physical and chemical characters, have given rise to divergences of appreciation by experts, have been eliminated. So also certain well-known species, but which, by the want of constancy in their results, appeared to be species liable to variation rather than well-defined types, have been rejected. Only one of these determinations, so as to well show in it this very elastic character, has been included. These are the two sorts, *Sarapong* or *Souni*. Care has been taken not to mention those numerous anomalous mixtures daily put on the market, the work of Chinese intermediaries, any more than the kinds called *reboiled*, of altogether inferior quality, which

originate most often in the bottoms of cellars and in the bottoms of the holds of ships. It is impossible to buy from an importer a lot of authenticated origin. The lots must be bought as they come, *i.e.* as the Singapore or Macassar merchant constitutes them. The lots marked by an assemblage of letters, which vary with the firms, are made solely according to their mechanical properties. This occasions, after each delivery, surprises which are often very disagreeable. Some species arrive ordinarily, with a certain specific resistance, and here is a fresh consignment under the same mark, possessing a specific resistance ten times greater. It very simply happens that one of the kinds generally employed in making up the lot happens to be wanting, and has been replaced by another sort which, at first sight, seemed to present the same properties. If that be a matter of little importance, so far as the ordinary uses to which gutta percha is put are concerned, where cheapness is more important than durability, it is not so in the case of electric cables, especially submarine cables. All those laid have a rather low insulation, and their success has been complete, whilst so much cannot be foretold in regard to the durability of species showing a high insulation, since we want experience on this subject, and the little that we do know does not enable us to hope for anything very good. Now, amongst all the species just enumerated in the order of their approximative value which they have shown in practice—an order which is about that of the specific resistance—it will be seen that the Sumatra species do not shine in the first rank, and consequently the best species of that isle may not indeed be the best species to propagate. If, therefore, we almost know the guttiferous trees of Sumatra and the western coast of the Malay Peninsula, yet we are still very ignorant of the sources of the eastern coast of Malacca and those of Borneo. Now the gutta percha of Sumatra has never been regarded as the best sort, and the superiority has always been accorded to the kinds called "Macassar," and these sorts in reality are only species coming from Banjermassin, Kotaringin, Coti, Bolungan, Sandekan. The Isle of Celebes does not belong to the guttiferous zone properly speaking, and, so far as known, does not contain guttiferous trees. As to the State of Pahang, it only recently put on the market products the quality of which surpasses all others, and thus confirms the indications furnished by Seligmann Lui. Yet it is difficult to admit that the Pahang as well as the Borneo sorts are the products of any *Palaquium.*

The gutta perchas of this origin are characterised by immediate thickening of the juice, which causes it to be impossible to collect the latter free from fragments of bark. All explorers are unanimous on this point. Moreover, the gutta percha which comes from these trees is always coloured by the colouring principle of the bark, when it is purified by boiling water. Again, the yield of an adult *Palaquium* is always very small. Nevertheless, what do we see? Pahang gutta percha is yellowish white, and contains very few impurities. That can only imply two things: either the flow of the juice is abundant and coagulation is not immediate, and things go on as in the case of *Payena Lerii*, the trees of Soupayang and Halaban, or that the gutta percha of this kind is indeed very pure, and is not of the same species as that of the *Palaquium*, since it has assumed no coloration at the expense of the bark during purification. As we have no information as to the yield of the guttiferous trees of Pahang, nor as to the method of exploitation, we can only base our reasoning on hypotheses; but, in regard to the guttas of Borneo, we possess further information in the report of Leys, which is in absolute contradiction as to the results yielded by a *Palaquium*, both in regard to yield and coloration. It is therefore admissible to think that the guttiferous tree of North Borneo is not a *Palaquium*. *Sandakan.*—The gutta of *Sandakan* resembles that of *Pahang*; it is very pure and yellowish white in colour. That of *Sarawak* is much redder, but it is at the same time very mixed with fragments of bark which would appear to be added over and above, and there is always found in it white veins very free from foreign matter. *Pontianak.*—It is very difficult to give an opinion on the provinces of *Pontianak*; however, trees of the genus *Palaquium* have been signalised in this region. *Kotaringin* and *Banjermassin.*—The two

neighbouring species *Kotaringin* and *Banjermassin* are interesting to compare. *Kotaringin*, a very fine gutta, is sometimes even quite white, whilst the *Banjermassin* is always heavily charged with bark débris, and always strongly coloured. If the presence of fragments of bark were inherent to the method of collection, and, as has been described in the case of the *Palaquium*, the gutta ought to undergo a certain number of manipulations to be freed from it, it would be the *Kotaringin* which should be the most wrought and the most coloured. Now, absolutely the contrary is the case. It is therefore probable that the impurities of *Banjermassin* are added afterwards *to mislead researches and preserve the monoply of an industry which is certainly lucrative.* The gutta of *Maragulia*, very white and containing few impurities, gives rise to two considerations. The gutta perchas of *Bagan* and of *Pekan* present something very peculiar which separates them not only from the *Palaquium* guttas but from the guttas of which we have just spoken. They greatly resemble, in all their properties, the *Balata* of the *Mimusops balata*, and we believe that *Bagan* gutta percha, in particular, may not indeed be the result of the coagulation of a juice, but rather of an evaporation such as that practised in Guiana, or some analogous operation.

As to the *Sumatra* kinds, they are the products of the *Palaquium oblongifolium*, more or less mixed with that of the *Payena Lerii*, with *Bouha-balam* and other trees incompletely studied. The gutta percha of *Padang* exhibits many of the properties described by all explorers as characteristic of the *Palaquium*: fragments of bark, red colour, etc. As regards *Souni*, it is simply an indeterminate mixture in diverse proportions.

A very difficult question is the origin of the *Bolungan* and *Coti* kinds. Were it not for their specific resistance, we could apply to them the remarks made regarding other *Borneo* species. But here we have a high specific resistance, and much higher the more recent the collection of the samples. Nos. 29, 30, and 32 of Table XCIII. are kinds collected some ten years ago. All the others are more recent. The reason, no doubt, arises from mixtures now made by the natives, because species of the Sandakan genus are now awanting and no longer suffice to meet the consumption. The greater specific resistance is probably due to the addition of the juice of the *Payena Lerii.* This tree yields a juice with a higher specific resistance, as Nos. 35 and 36 of Table XCIII. show; but this juice has at endency to resinification, and the specific resistance is then lowered at the same time that the gutta percha becomes brittle (see Nos. 37 and 38), which explains why they systematically rejected, in the making of cables, the exclusive use of gutta perchas of high insulation. A certain amount is indeed required, but the dose strictly necessary for the futherance of the work must not be exceeded, unless miscalculations occur, which, from being a long time in maturing, are none the less grave on that account, as the inconvenience may only supervene when the responsibility of the manufacturer has ceased.

The species from *Assahan*, Trenganu, and the white gutta of *Pahang*, are certainly mixtures of the juices of the *Payena* with the *Bouha-balam.* In No. 43 of Table XCIII. an analysis of this latter product is given, which shows that the resin present in it is twice the amount of the gutta. All these white gutta perchas have a weaker specific resistance than that of *Payena* gutta percha. Perhaps this may be due to the mixture of the *Payena* with the very resinous gutta *Bouha-balam*; but it is impossible to verify this assertion, because it is not possible to determine the specific resistance of this latter product.

Summary (Leon Brasse).—1. All gutta perchas of superior quality have a feeble specific resistance, and it is in no way demonstrated that they are the products of the *Palaquium.* 2. The *Pahang* gutta, product of the *Palaquium oblongifolium*, is a gutta percha of average quality, and its specific resistance is rather high. 3. The *Bolungan* and *Coti* gutta used in the past had a feeble resistance. Those which come to market now have a higher and higher. It is necessary to use them with great prudence. 4. The white guttas each exhibit a high resistance; they can neither be employed alone nor in large proportion for the manufacture of

TABLE XCIII.—THE VARIETIES OF

Consecutive Number of Sample.	Variety.	Origin of the Variety.	Form of the Cakes.	Coating of the Cakes.	Section of the Cakes.	Nature and Amount of Impurities.
1	Pahang.	State of Pahang. East coast of Malay Peninsula.	Generally small, the pear-shaped lumps weighing not more than $1\frac{1}{10}$ to $2\frac{1}{4}$ lb. Flat lumps with rectangular base, reaching $6\frac{3}{5}$ lb. at the most.	Yellowish, rarely reddish, more often inclining to green.	Yellowish white, very rarely reddish yellow. Compact, rarely foliated.	A little woody matter. 33 per cent.
2	id.	id.	id.	id.	id.	id. 25 per cent.
3	id.	id.	id.	id.	id.	id. 33 per cent.
4	id.	id.	id.	id.	id.	id. 28 per cent.
5	id.	id.	id.	id.	id.	id. 24 per cent.
6	id.	id.	id.	id.	id.	id. 41 per cent.
7	Sandakan.	North-east of Borneo.	Lumps of $4\frac{3}{5}$ lb. in parallelipipedons with flat trapezoid bases elongated in the shape of boats; sharp angles. Moulded gutta.	Bright yellow colour.	..	A few fragments of bark, 22 per cent.
8	Maragulai.	?	Very flat cakes of $1\frac{1}{10}$ lb. or less, or in flat spindles or squares of $6\frac{3}{5}$ to $8\frac{1}{4}$ lb.	Greyish white; greyer spots.	Horny appearance.	No shapeless fragments of bark disseminated in the mass, but pieces of about 1·3 centimetre, all of the same shape, quite separate, and certainly added as make-weight.
9	Bagan.	Probably between Malacca and Singapore.	Pear-shaped lumps of $4\frac{2}{5}$ to $6\frac{3}{5}$ lb., or in carrots of $13\frac{1}{5}$ to $17\frac{3}{5}$ lb.	Wine colour, soapy touch, hot and cold.	More or less pronounced, unequal section, many holes in the mass coming from the imperfect juxtaposition of the fragments combined to form the cake.	Without fragments of disseminated bark, or at least very few of them. 29 per cent.
10	id.	id.	id.	id.	id.	29 per cent.
11	Banjermassin.	South of Borneo.	Sticks 80 centimetres ($31\frac{1}{2}$ inches) long by 10 to 15 centimetres (say 4 to 6 inches) in diameter, rounded at the extremities; or parallelipipedons of 50 to 60 centimetres (20 to 24 inches), with acute angles in the shape of pig lead, bearing on two opposite faces sculpture, representing an ornamental monster on the one face and foliage on the other.	Spongy appearance. More or less brown and even black.	Section. Salmon-red, foliated.	Many fragments of bark. 45 per cent.
12	id.	id.	id.	id.	id.	40 per cent.

RAW COMMERCIAL GUTTA PERCHA.

Valuation of the Quality.	Nature of the Thread.	Ratio of the Gutta to the Resin.	Specific Resistance in Megohms-Centimetres.[1]	Remarks.
Good working quality; hard; very nervous; regains its pristine hardness very quickly on cooling.	Slightly rugose.	6·20	62·10	..
id.	*id.*	4·60	16	..
id.	*id.*	4·94	50	..
id.	*id.*	3·89	15	..
id.	*id.*	5·75	5	..
id.	*id.*	5·25	28	..
As above.	Thread more smooth.	2·29	56	This gutta percha would appear to be rolled before moulding.
Very hard gutta, cooling quickly.	Rugose thread.	1·27	43	..
Rather hard and nervous gutta, cooling quickly.	Very smooth thread.	1·47	30	Smell of opium. Gutta difficult to clean. Much resembles Balata by its behaviour on cleaning and on drawing out into a thread.
id.	*id.*	1·42	17	..
Gutta very hard and very nervous; cools quickly.	Rugose thread.	4·00	141	..
id.	*id.*	2·20	52	..

[1] Obach's determinations of the *insulation in megohms* and inductive capacity in microfarads per cubic knot of the various brands of commercial gutta percha are given in Tables XI. and XIV., pp. 63 and 66 of his *Cantor Lectures*.—Tr.

TABLE XCIII.—THE VARIETIES OF

Consecutive Number of Sample.	Variety.	Origin of the Variety.	Form of the Cakes.	Coating of the Cakes.	Section of the Cakes.	Nature and Amount of Impurities.
13	Kotaringin.	South of Borneo.	Spindles pointed at both ends, square or flat section from $1\frac{1}{10}$ to $2\frac{1}{5}$ lb., and square parallelipipedons of $6\frac{3}{5}$ to $8\frac{4}{5}$ lb. with slightly attenuated and rounded extremities.	Colour brighter than Banjermassin.	Salmon-red, foliated.	32 per cent.
14	*id.*	*id.*	*id.*	*id.*	*id.*	26 per cent.
15	Pekan.	State of Pahang on the coast.	Cakes of 4 to 5 centimetres (say $1\frac{1}{2}$ to 2 inches) thick, weighing $4\frac{2}{5}$ to 11 lb.	Deep reddish plum-brown with a mouldy appearance.	Wine red; very homogeneous.	Few impurities. 23 per cent.
16	*id.*	*id.*	*id.*	*id.*	*id.*	29 per cent.
17	Sarawak.	North-west of Borneo.	Cakes light in weight compared with their size when dry.	Spongy cakes; varicose reticulated surface, with imbedded bark, brown, earthy.	Reddish white section with white veins.	Many fragments of bark. 50 per cent.
18	*id.*	*id.*	*id.*	*id.*	*id.*	45 per cent.
19	Pontianack.	South-west of Borneo.	Blocks of 11 to 22 lb.	Very spongy cakes. Reddish yellow, more grey than Sarawak.	Same section as Sarawak with white or grey veins.	Loaded with impurities. 44 per cent.
20	*id.*	*id.*	*id.*	*id.*	*id.*	33 per cent.
21	Padang.	West of Sumatra.	Blocks in form of very much flattened square parallelipipedons of about $5\frac{2}{5}$ lb., branded, or more bulky cakes up to 66 lb.	Very deep reddish yellow.	Same section as the coating; it is decidedly foliated.	Large amount of débris. 40 per cent.
22	Sarapong or Souni.	East of Sumatra.	Oval-shaped cakes with pointed attenuated extremities of $1\frac{1}{10}$ to $2\frac{1}{5}$ lb.	Surface rugose and earthy.	Homogeneous yellowish white section.	Very peculiar. 30 per cent.
23	*id.*	*id.*	*id.*	*id.*	*id.*	27 per cent.
24	Siak.	East of Sumatra.	Sticks of $4\frac{2}{5}$ to $6\frac{3}{5}$ lb., swollen towards the middle.	Reddish yellow.	Brighter tint on cutting; foliated appearance.	Heavily loaded with bark. 50 per cent.

RAW COMMERCIAL GUTTA PERCHA—*continued.*

Valuation of the Quality.	Nature of the Thread.	Ratio of the Gutta to the Resin.	Specific Resistance in Megohms-Centimetres.[1]	Remarks.
Slightly less nervous than Banjermassin.	Rugose thread.	4·82	25	..
id.	*id.*	4·89	11	..
Slightly hard, nervous; cools difficultly.	Smooth thread.	1·03	90	..
id.	*id.*	1·42	17	..
Very nervous; cools well; very good quality.	Rugose thread.	3·23	65	..
id.	*id.*	2·85	128	..
Very good gutta.	Rugose thread.	3·57	141	..
id.	*id.*	3·02	171	..
Hard and nervous; cools well.	Nervous thread.	2·24	457	Owing to its high insulation, it is not possible to use the pure article for telegraphic purposes.
Inferior quality; rather hard, but little nervous; cools well.	Thread very smooth.	1·49	137	Under the name of Souni are included a number of mixtures made by the natives of Sumatra. These mixtures contain various proportions of red and white gutta. Here is a formula which Seligmann Lui saw made up with his own eyes: Gutta Derrian (*Dichopsis oblongifolia*) . . . 2 Gutta Sundeck (*Payena Lerii*) . . . . 3 Gutta Pouteh (*Bouha-balam*) 1 No. 22 is the type of a good mixture for telegraph cables.
id.	*id.*	1·42	692	..
Rather hard; little nerve; cools quite well.	Thread very smooth.	1·05	900	This is a gutta of the Souni kind. The type examined is a very bad one of the kind.

[1] See note, p. 343.—Tr.

TABLE XCIII.—THE VARIETIES OF

Consecutive Number of Sample.	Variety.	Origin of the Variety.	Form of the Cakes.	Coating of the Cakes.	Section of the Cakes.	Nature and Amount of Impurities.
25	Bolungan.	East of Borneo.	Cakes of invariable size, in form of lumps terminated by an œillet. Made by folding the thin part of the mass on the body of the latter, several convolutions being made. Small cakes of $4\frac{2}{5}$ to 11 lb., the best in large cakes weighing as much as 66 lb.	Blackish, almost fuliginous, knotty, like badly trimmed sticks or batons.	White or violet coloured, allowing a juice to exude which solidifies immediately in contact with the air. Foliated.	Very peculiar, but adulterated with bulky pieces of bark from 5 to 20 grammes ($\frac{1}{6}$ to $\frac{2}{3}$ of an ounce), sometimes 50 grammes (say $1\frac{3}{4}$ ounce), all of the same shape and nature, and coming probably from the producing tree; they are all too similar not to belong to the same species, and as they are never absent they certainly belong to a species which is met everywhere in the neighbourhood of the gutta tree, and most likely to the latter itself. 30 per cent.
26	,,	,,	,,	,,	,,	30 per cent.
27	,,	,,	,,	,,	,,	46 per cent.
28	,,	,,	,,	,,	,,	45 per cent.
29	,,	,,	,,	,,	,,	27 per cent.
30	Coti.	East of Borneo.	Cakes all of the same size, consist of sticks of 80 centimetres ($31\frac{1}{2}$ inches) long by 15 centimetres (say 6 inches) in diameter, made by rolling up a thin sheet. The extremities of the roll are held in the hand. They preserve the form of the fingers which have kneaded the gutta percha whilst still hot.	Reticulated appearance. The meshes of the network filled by fragments of wood of a viscous yellowish or reddish yellow colour. Some sticks are branded, and then are more reddish.	Decidedly foliated, yellowish or greyish white. Like Bolungan, allows a liquid to exude. More reddish on cutting.	But little bark. 30 per cent. More bark débris.
31	,,	,,	,,	,,	,,	26 per cent.
32	,,	,,	,,	,,	,,	33 per cent.
33	,,	,,	,,	,,	,,	33 per cent.
34	,,	,,	,,	,,	,,	42 per cent.
35	Cotoman.	..	Small cakes in the form of a torsade (twisted spiral) of $4\frac{2}{5}$ to $6\frac{3}{5}$ lb.	Very smooth surface.	Very white, allowing a viscous exudation to escape.	30 per cent.
36	Keletan.	North-east of Malay Peninsula; north of Pahang.	Cakes of $1\frac{1}{10}$ to $2\frac{2}{5}$ lb., in form of balls of twine analogous to the rubber balls of Africa.	Recent, waxy rose appearance. Old, white chalky.	..	30 per cent.
37	,,	,,	,,	,,	,,	40 per cent.
38	,,	,,	,,	,,	,,	33 per cent.

RAW COMMERCIAL GUTTA PERCHA—*continued.*

Valuation of the Quality.	Nature of the Thread.	Ratio of the Gutta to the Resin.	Specific Resistance in Megohms-Centimetres.[1]	Remarks.
Hard, nervous gutta ; cools well.	Rugose thread.	3·52	304	It is the best gutta amongst those of high insulation. It is very difficult to work.
,,	,,	1·26	310	..
,,	,,	2·47	208	..
,,	,,	3·39	780	..
,,	,,	3·03	30	..
Hard, rather nervous; gutta cools well.	Thread smooth.	1·87	72	Quality absolutely comparable with Bolungan gutta.
Better quality.	..	..	..	..
,,	,,	1·81	120	..
,,	,,	1·54	43	..
,,	,,	1·90	453	..
,,	,,	1·20	829	..
Hard gutta, but wants nerve.	Thread very smooth.	1·56	3045	Smell of sweat ; old cheese. Loss on washing, 30 per cent., of which only 2 per cent. is solid matter.
Very nervous and friable. Not very hard on the whole, and totally wanting in nerve, and does not cool very well.	Thread very smooth.	1	2101	Two kinds of gutta are included under this name. One has a peculiar appearance, which shows that it is much as collected ; that is the *virgin gutta* No. 26.[2] The other consists of two parts, one inferior in the centre, but covered on the surface with a better layer. This second quality gutta yields a product which becomes brittle in a short time.
,,	,,	0·95	743	..
,,	,,	0·98	1038	..

[1] See note, p. 343.—Tr.

[2] ? 36.—Tr.

TABLE XCIII.—THE VARIETIES OF

Consecutive Number of Sample.	Variety.	Origin of the Variety.	Form of the Cakes.	Coating of the Cakes.	Section of the Cakes.	Nature and Amount of Impurities.
39	Pahang-white.	State of Pahang.	Large round cakes, in balls larger than a man's head.	White chalky.	Friable.	40 per cent.
40	*id.*	*id.*	*id.*	*id.*	*id.*	19 per cent.
41	Assahan.	North-east of Sumatra.	Same appearance as above.	*id.*	*id.*	20 per cent.
42	Tringanou.	North-east of the Malay Peninsula; on the shore of Kelatan.	*id.*	*id.*	*id.*	31 per cent.
43	Bouha-balam.	Malacca.	Fragments of no shape, which must be quickly blocked for fear of crumbling to powder.	,,	,,	,,
44	Gutta Pouteh.	Sumatra.	..	..	..	..
45	Balata.	Guiana and Venezuela.	Greyish blocks, or reddish plates of 1 to 2 centimetres in thickness, preserving the form of the boxes in which the juice has been dried. Width of the rectangular blocks, 0·40 metre (17·6 inches). Length, 0·80 metre (31½ inches).	Vague appearance of dried skins, soapy to the touch.	..	Very little foreign matters; little bark. Often mixed with lime. The natives have for a certain time adulterated the juice with water, adding lime to bring back its consistency.

TABLE XCIV.—ANALYSIS OF VARIOUS BRANDS OF COMMERCIAL

Genuine from Palaquium Sp.		Pahang.				Bolungan Red.				Banger Red.			
		D=0·9858. $\frac{G.}{R.}$ 3·9.				D=0·9911. $\frac{G.}{R.}$ 3·4.				D=0·9868. $\frac{G.}{R.}$ 4 0.			
		A.	I.	II.	III.	A.	I.	II.	III.	A.	I.	II.	III.
Composition.	Gutta	57·0	61·5	54·7	52·1	51·8	53·5	48·1	41·4	40·7	46·5	41·5	35·5
	Resin	13·3	13·1	13·8	14·0	18·2	17·5	21·9	23·8	20·0	18·9	20·4	22·8
	Dirt	11·5	10·0	16·1	14·1	10·8	9·0	12·2	12·0	17·4	13·1	17·4	19·2
	Water	18·2	15·4	15·4	19·8	19·2	20·0	17·8	22·8	21·9	21·5	20·7	22·5
G. P. (G.+R.)		70·3	74·6	68·5	66·1	70·0	71·0	70·0	65·2	60·7	65·4	61·9	58·3
Waste (D.+W.)		29·7	25·4	31·5	33·9	30·0	29·0	30·0	34·8	39·3	34·6	38·1	41·7
Ratios.	$\frac{G.P.}{Waste}$	2·4	2·9	2·2	2·0	2·3	2·4	2·3	1·9	1·5	1·9	1·6	1·4
	$\frac{G.P.}{Resin}$	4·3	4·7	4·0	3·7	2·8	3·1	2·2	1·7	2·0	2·5	2·0	1·6
Gutta Percha Proper.	Gutta	81·1	82·4	79·8	78·9	74·0	75·4	68·7	63·5	67·1	71·1	67·1	60·9
	Resin	18·9	17·6	20·2	21·1	26·0	24·6	31·3	36·5	32·9	28·9	32·9	39·1
Lots		93	26	13	15	37	10	6	6	91	28	27	22
Tons		233	54½	26½	28½	60	10	3	3¼	232	35	39¼	48¼

A = Average of all grades; I., II., III., different grades. D = density. $\frac{G.}{R.}$ = ratio of

RAW COMMERCIAL GUTTA PERCHA—*concluded.*

Valuation of the Quality.	Nature of the Thread.	Ratio of the Gutta to the Resin.	Specific Resistance in Megohms-Centimetres.[1]	Remarks.
Soft, enough nerve; cools well, tacky.	Very smooth thread, but difficult to work alone, as it adheres to the rolls.	1·15	800	The surface of the cake is often formed by a layer of nervous gutta a few centimetres thick. The fresh cakes have a smell of ripe cheese.
..	,,	1·16	743	..
Quality slightly inferior to the preceding; more tacky; does not cool so well.	*id.*	0·90	743	,,
id.	,,	1·18	743	,,
Soft gutta without nerve; does not cool at all, *i.e.* even after several days of cooling the plates of this substance are capable of sticking together. They must be powdered with talc to prevent them from uniting to a single block.	Cannot be wrought alone, as it is too tacky.	0·52	Impossible to determine.	Producing tree (not described), which grows in the marshy districts of the gutta percha countries, and which is used to adulterate all sorts a little. Very little used in spite of its low price, probably because there is already sufficient of it in the white gutta percha, which is used to render the working of the good kinds possible.
..	..	..	..	..
Soft gutta; very nervous; slightl elastic. Cools very slowly.	..	1·49	300	Forms the transition between rubber and gutta percha. Heated, it does not soften enough so as to be used for insulating wire like gutta percha. It is employed in mixtures, to which it communicates its slowness of cooling.

RAW GUTTA PERCHA DURING 1889–96 (OBACH).

Soundi from Payena Sp.										White from Unknown Species.								Mixed and Reboiled from Unknown Sources.		
Bagan.			Kotaringin.				Sarapong.			Bolungan.			Mixed.	Banger.				Sarawak Mixed.	Padang Reboiled.	Banca Reboiled.
D=0·9709. G./R. 1·44.			D=0·9729. G./R. 1·3.				D=0·9767. G./R. 1·38.			D=1·0093. G./R. 1·57.										
A.	I.	II.	A.	I.	II.	III.	A.	I.	II.	A.	I.	II.	A.	A.	I.	II.	III.	A.	A.	A.
44·1	44·2	43·7	46·1	48·8	45·0	42·1	39·5	40·6	38·5	37·9	40·3	35·3	34·5	26·8	29·9	26·1	22·5	34·7	26·5	33·5
30·4	29·7	32·2	31·5	29·9	32·3	33·7	30·9	29·5	32·3	31·7	30·7	33·0	30·0	24·5	25·1	23·4	31·1	25·6	30·3	39·1
6·3	6·2	6·8	8·3	7·6	8·6	9·1	3·3	3·1	3·6	10·2	10·1	10·4	5·6	14·8	12·9	15·6	14·7	15·0	13·4	5·6
19·2	19·9	17·3	14·1	13·7	14·1	15·1	26·3	26·8	25·6	20·2	18·9	21·3	29·9	33·9	32·1	34·9	31·7	24·7	29·8	21·8
74·5	73·9	75·9	77·6	78·7	77·3	75·8	70·4	70·1	70·8	69·6	71·0	68·3	64·5	51·3	55·0	49·5	53·6	60·3	56·8	72·6
25·5	26·1	24·1	22·4	21·3	22·7	24·2	29·6	29·9	29·2	30·4	29·0	31·7	35·5	48·7	45·0	50·5	46·4	39 7	43·2	27·4
2·9	2·8	3·2	3·5	3·7	3·4	3·1	2·4	2·3	2·4	2·3	2·4	2·2	1·8	1·1	1·2	1·0	1·2	1·5	1·3	2·6
1·5	1·5	1·4	1·5	1·6	1·4	1·2	1·3	1·4	1·2	1·2	1·3	1·1	1·2	1·1	1·2	1·1	0·7	1·4	0·9	0·9
59·2	59·8	57·6	59·4	62·0	58·2	55·5	56·1	57·9	54·4	54·5	56·8	51·7	53·5	52·2	54·4	52·7	42·0	57·5	46·7	46·1
40·8	40·2	42·4	40·6	38·0	41·8	44·5	43·9	42·1	45·6	45·5	43·2	48·3	46·5	47·8	45·6	47·3	58·0	42·5	53·3	53·9
33	15	10	69	25	22	22	62	26	24	45	22	23	55	83	34	34	15	100	36	47
36	16¼	10½	71	32¼	23¼	15½	101	37	42¾	156	83½	73	227	259	68	168	23	579	190	138

gutta percha to resin in separate samples used to determine density.

[1] See note, p. 343.—Tr.

cables. 5. Finally, one cannot believe that it was the product of a *Palaquium* which was used by itself alone as the dielectric of the submarine cables laid in the beginning. Its specific resistance is always about $400\ 10_2$ megohms, and we do not know of a cable, in Great Britain at least, the specific resistance of which exceeds $120\ 10^6$ megohms. 6. The best quality of gutta percha is that of Pahang, Sarawak, and Sandakan.

TABLE XCV.—ANALYSIS OF GETAH TABAN MERAH AND GETAH SOONDIE FROM VARIOUS SOURCES (OBACH).

Description.		Percentage Composition.				Totals.		Ratios.		Percentage Composition		Quality.
Type.	Name and Source.	Gutta G.	Resin R.	Dirt. D.	Water W.	G.P. (G.+R.)	Waste (D.+W.)	G.P./Waste	Gutta/Resin	Gutta Q.	Resin R.	$\left(\frac{r}{10}\right)$ G.
Getah Taban (Merah)	1. Gutta Taban (from Selangor)	75·5	13·5	2·0	9·0	89·0	11·0	8·1	5·6	84·8	15·2	1b
	2. Pahan Taban	68·8	10·1	5·4	15·7	78·9	21·1	3·7	6·8	87·2	12·8	1a
	3. Getah Taban Merah (*Dichopsis Gutta*, Benth.)	66·7	14·0	6·2	13·1	80·7	19·3	4·2	4·8	82·6	17·4	1c
	4. Pahang A.	66·2	11·6	13·2	9·0	77·8	22·2	3·5	5·7	85·1	14·9	1b
								Mean		84·9	15·1	1b
Getah Soondie	5. Gutta Mantah (from Borneo)	50·8	38·9	9·3	1·0	89·7	10·3	8·7	1·3	56·6	43·4	4a
	6. Gutta Sundek (*Payena Lerii*)	46·4	34·7	2·6	16·3	81·1	18·9	4·3	1·3	57·2	42·8	4a
	7. Getah Sundek (*Payena spec.*)	43·0	32·6	5·1	19·3	75·6	24·4	3·1	1·3	56·9	43·1	4a
	8. Goolie Soondie (from Bagan)	51·5	38·3	2·8	7·4	89·8	10·2	8·8	1·3	57·4	42·6	4a
								Mean		57·0	43·0	4a

Particulars of above samples.—1. Colonial and Indian Exhibition, 1886, Straits Settlements, very light pinkish, not dense, yielded light pinkish brown gutta; hard dark brown resin. 2. Singapore market, 1890, very light, clean, not dense, yielded very light brown strong gutta, and nearly hard light brown resin. 3. H. N. Ridley, Esq,. F.L.S., Singapore, 1892, light pinkish, brown, clean, dense, yielded light pinkish, very strong gutta, and hard reddish brown translucent resin. 4. Homogeneous piece picked out from large lot 1897, yielded pink, dense, little fine bark gutta, and hard, very dark-brown resin. 5. James Collins, Esq., 1880, Kew Gardens, very light, crumbling, clean, yielded very light brownish gutta, and hard yellowish brown resin. 6. Sir Hugh Low, Perak, 1885, Kew Gardens, very light, dense, clean, yielded nearly colourless gutta, and very soft light brown resin. 7. H. N. Ridley, Esq., Singapore, very light, dense, clean, yielded nearly white, very strong gutta, and very soft light brown resin. 8. Homogeneous piece picked out from large lot 1897, very light, dense, clean, yielded very light brown, very strong gutta, and soft light yellow resin.

TABLE XCVI.—ANALYSES OF SINGAPORE GUTTA PERCHAS BY VAN ROMBURG AND TROMP DE HAAS.

	Dirt.	Water.	Resins.	Gutta.	Price per picul.
					$
Bila of red Soondi	33·6	7·0	31·4	28·0	150
Sarawak Soondi No. 2	37·1	6·8	25·5	29·6	135
Penang Gutta Palelo No. 1	2·1	5·8	53·8	38·3	180
Sarawak red Soondi No. 1	19·0	3·9	35·5	41·6	350
Bagan white Soondi No. 1	0·7	8·6	36·5	54·2	350
Koatei Gutah Merah No. 2	21·7	5·1	28·5	44·7	360
Indragiri white Soondi	2·0	4·1	46·2	47·7	370
Sambas white Soondie	1·0	4·4	53·6	41·0	380
Koatei Gutah Merah No. 1	14·8	3·8	34·8	46·6	500
Pahang white Soondie No. 1	4·2	0·5	12·8	82·5	500

CHAPTER V

PHYSICAL AND CHEMICAL PROPERTIES OF GUTTA PERCHA

FROM the previous details the reader will readily appreciate how difficult is the examination of the physical and chemical properties of a substance so variable in composition, and the properties of which differ infinitely from one species to another. How can a substance of which not even the real botanical origin, which, most generally, is only a simple mixture of several products of different origin and different properties, be determined with any scientific certitude.

Still more than in the case of indiarubber, we regret that researches up to now have only been on goods imported into Europe, and that the latex of the *Sapotaceæ* and the gutta percha derived therefrom have not been examined in a methodical manner on the spot of production. In default of such data, it would have been desirable to examine the properties of a gutta percha taken from the wrapping of a cable, the good qualities of which had been tested for a length of time. This resource also failed us, as it failed our predecessors.[1] Dr. Miller in 1860 was indeed able to study the chemical composition of the gutta percha used in the construction of a cable, but this cable was of recent construction, and its qualities had not been consecrated by time. We therefore condense the observations made and the results obtained, not upon a natural product of certain origin, but on a simple commercial type, even though this type be often described as pure *Isonandra* gutta.

Colour, *smell*, *etc.*—The latex is coloured by a certain amount of colouring matter which exudes from the bark when incised, and this colour is embodied in the resultant gutta percha. Certain species impart a characteristic colour to their product, so the Chinese boil low grades with bark of best species to get the desired colour. Pure gutta percha is colourless; translucid when thin. But a cut slice, $\frac{1}{5}$ of a millimetre thick, laid on a white surface shows a special coloration varying between rose and greyish white. Under the polariscope, it presents a magnificent appearance, appearing to consist of prisms which sink into each other, and so give rise to the most varied hues. It is inodorous and insipid, and it is only under the action of certain transforming and decomposing agents that it assumes an acrid characteristic smell. *Structure.*—It possesses naturally a cellular structure, but when strongly pulled it is drawn out and its texture becomes fibrous, and in this condition it is much more resistant. If its length be doubled, by a strong pull it supports without breaking the action of a force double that which has been required to stretch it. But it does not exhibit resistance in every direction, like indiarubber, and it is easily torn under the action of a transversal force.

This cellular structure, capable of modification and of passing to the fibrous state, is not equally developed in all kinds of gutta perchas, and in general the more easily a gutta percha passes from one condition to another, the more it possesses the requisite qualities, and the more it is separated from those bastard species known under the name of gutta-caoutchoucs. But exaggeration of this structure leads to too brittle gutta perchas, which cannot be used alone in cable-making. Gutta percha does not amalgamate or join with itself at the ordinary temperature. If, however, two surfaces be heated, placed in contact, and

[1] The necessary data have since been supplied by Obach, Table CII., p. 361.—TR.

simultaneously pressed rather energetically, the parts in contact join and form a single piece, which is quite incapable of reverting to its first position. But in this operation care must be taken not to use too great a heat, because when the gutta reaches its melting-point it remains pitchy after cooling, and is no longer endowed with its natural properties.

Tensile strength.—At the ordinary temperature gutta percha is solid, pliant, very tenacious, but slightly elastic. It does not break until submitted to a load of 24·5 kilos. per square millimetre, whilst elongating, according to the species, 50 to 60 per cent. It may be folded, tied, and drawn without inconvenience, but it is easily cut by a point or by a cutting instrument. Its elasticity in that condition is that of softened leather.

TABLE XCVII.—TENACITY OF GUTTA PERCHA, COHESIVE PROPERTIES OF GUTTA PERCHA TUBES OF DIFFERENT DIMENSIONS, AND TENSILE STRENGTH OF GUTTA PERCHA (STORER AND STODDER, 1856).

Length of the Tubes in Metres.	Interior Diameter in Metres.	Exterior Diameter in Metres.	Pressure per Square Centimetre.	
			Supported in Kilogrammes.	Occasioned Rupture Kilogrammes.
30·4779	0·0254	0·0301	7·02770	...
Samples varying in length from 0·0254 metre to 0·0762.	...	...	18·69368	19·11534
	...	0·0302	21·08310	22·48864
	0·0255	0·0285	19·67756	21·36421
	0·0160	0·0262	22·48864	25·29972
	0·0127	0·0160	16·44482	16·86648
	0·0127	0·0160	25·29972	and ruptured
	0·0063	0·0160	50·59944	53·41052

The tensile strength of gutta percha is the chief mechanical property of interest to the technologist. When gutta percha is subjected to a pulling force it becomes more resistant. When a thin strip is pulled it at first stretches easily, but after a certain point it becomes so resistant to stretching that it cannot be elongated any further. If a thin rod of gutta percha with a thickened end, technically termed a "gut," be hung from the bracket at the top of the stand *S*, and a weight *w* of 4 lb. applied to it, it stretches at once to a certain point on the scale *s*, but it does not break even if twice that weight be applied, although the gut has become considerably thinner than at first. (Fig. 117). If it now be loaded with say 21 lb. it stretches further, and then, if the experiment be carefully made, and the breaking strain per square inch of original area taken as usual, it would work out

TABLE XCVIII.—ELASTICITY OF GUTTA PERCHA.

	Length of the Band in Metres.	Contraction due to Elasticity in Metres.
Unloaded	0·66628	...
Loaded with 3 kilogrammes	0·66987	...
,, 2·5 ,, ...	0·67944	0·00043
,, 2·0 ,, ...	0·66904	0·00040
,, 1·5 ,, ...	0·66850	0·00046
,, 1·0 ,, ...	0·66795	0·00063
,, 0·5 ,, ...	0·66758	0·00037
,, 0·4 ,, ...	0·66679	0·00097

between 2000 to 3000 lb. for that particular material; but if instead of the original area the final sectional area at breaking had been taken, the strain would have been found to be about 12,000 lb. per square inch. Gutta perchas with different percentages of resin have different breaking strains. Their tensile strength depends largely on the percentage of resin. A material having about 45 per cent. of gutta and 55 per cent. of resin, breaks at about 770 lb. to the square inch. When such resin is extracted by petroleum ether from the same material, it would stand up to about twice that breaking strain.

Dr. Sherman (*loc. cit.*), in reporting the results of certain tensile tests on various samples of gutta, remarks that, in order that the measurements made might be within the limits of the instruments at hand, only small strands of gutta percha could be used in testing. To make these strands free from minute air-bubbles was well-nigh impossible, in consequence of which the breaking was in most cases brought about by weakness due to this source. The figures, while thus only approximate, are below and not above the true values, and show, he claims, clearly the enormous tensile strength of his samples. Obach, continues Dr. Sherman, gives a tensile strength of 5000 lb. for the best gutta percha, while for the gutta from it he found about 6500, which closely corresponds with Sherman's results, and this, he claims, brings out most clearly the excellent quality of the best Philippine gutta percha.

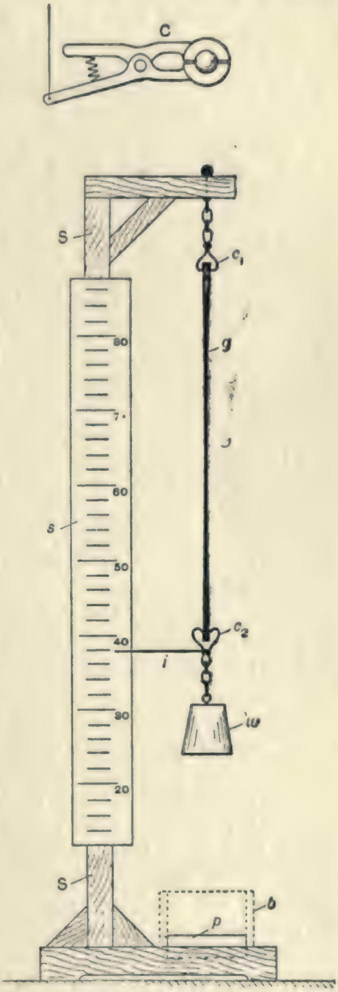


FIG. 117.—Golfball testing apparatus, as used by Obach, showing an actual application of stretching test.

Elasticity, etc.—Table XCVIII. gives results of careful experiments made by Adriani to determine the permanent expansion and elasticity of gutta percha. He likewise determined the weight capable of rupturing a gutta percha band with a given force. He used a piece of engine belt 0·001755 metre in thickness by 0·06 metre wide. The extension and contraction were determined by means of an ink tracer for drawing very fine lines, by which divisions of 0·00001 metre might be distinguished. The trials were made at a temperature of 17° C. (62·6° F.). Observations were taken every ten minutes, so that each result tabulated above is an average of six observations which together took an hour.

The elastic elongation for a weight of 3 kilos. is therefore equal to 0·00308 metre, the permanent elongation being 0·0005 metre. By loading the band more and more, it ruptured with 186 kilos.

The elongation, according to Obach, or the extent to which a "gut" stretches before it breaks, is also affected by the percentage of resin. In the last two cases cited under "tensile strength" the elongation was 460 and 500 per cent. respectively, but it also depends on the nature of the gutta percha.

Hardness—Resistance to pressure, to a blow, or to shearing.—These properties are also all influenced by the percentage of resin.

Permeability.—Gutta percha seems very impermeable, but in thin sheets, as obtained by the evaporation of a solution thereof in carbon disulphide, it would

appear to be endowed with a peculiar porosity: under the microscope, the cavities by which it is riddled are easily observed. These allow water to penetrate by the expansion of the sides of the cavities. The quantities of salt and soft water so absorbed by gutta percha are in the ratio to each other of 3 to 5. For sea water the absorbing power of the gutta becomes twice greater when the temperature rises from 4° to 49° C. (39°·2 to 120°·2 F.). In fresh water the increase is a little more rapid. Pressure has no appreciable influence on this property. The water absorbed seems to penetrate only to a certain very small depth into the pores of the gutta percha. Beyond this limit the weight of water does not increase, no matter how thick the block. The water, interposed mechanically, does not in any way alter the dielectric properties so long as it does not exceed 2 to 3 per cent. of the weight of the gutta percha. [Obach's results quite confirm this statement; see Table CXXIII., p. 397.]

Density.—The density of gutta percha, generally given as varying between 0·999 (Adriani) and 0·979 (Soubeiran), is in reality greater than that of water. This divergence is explained by Payen as due to the different methods of preparation of the gutta percha. He strongly compressed a band of softened gutta percha, and reduced under water the ribbons obtained in quantity into small fragments. The majority of these instantly fell to the bottom of the vessel, whilst others floated on the liquid for some time, to sink after having been sufficiently penetrated by the aqueous liquid. Gutta percha is thus only apparently lighter than water because of its porosity. This porosity is less the more care taken in purifying it. By compressing gutta percha its porosity is diminished and its density is increased. Payen's opinion is confirmed by numerous other scientists, and it is now admitted that the density of laminated gutta percha varies between 1·010 and 1·020.

Action of heat.—At 37° C. (98°·6 F.) gutta commences to soften, and its properties are so perceptibly modified that a gutta percha cable, after being made, should not, according to Wunschendorff, be submitted to a temperature above 32° to 33° C. (89°·6 to 91°·4 F). If the temperature rises to +50° C. (122° F.) the change is still more accentuated, and if we can knock it about with impunity or hurl it against a wall in this condition, it, on the other hand, becomes very sensitive to a slow pressure exerted on its flat surface. It is capable of receiving the most fine and delicate impressions, which it afterwards retains. At 90° C. (194° F.) it becomes adhesive and undergoes a sort of pasty fusion, which enables it to be kneaded and moulded at will. All imaginable shapes may thus be given to it, and these remain permanent when it has regained the normal temperature. This characteristic property, likewise possessed—though to a less extent—by other plastic substances, is due to the air interposed in the pores of the substance. Masticated gutta percha swells in a vacuum, and its surface tears. If it be very dense it does not immediately swell in the bell of the air-pump, but if it be immersed in mineral oil, and a vacuum be afterwards made, it gives rise to an abundant and prolonged disengagement of air. Thus prepared, and again exposed to the open air, it loses its property of hardening after cooling, and resembles strongly greased leather. At 100° C. (212° F.) the pasty fusion is completely terminated, the substance resinifies in contact with air, absorbing one-quarter of its weight of oxygen. At 130° C. (266° F.) it melts; heated further it boils and distils, leaving a light block of charcoal as a residue. The colourless oils from this distillation consist principally of isoprene and caoutchene. Gutta percha does not lose its suppleness at 10° C. below zero (14° F.), whilst rubber is very sensitive to cold.

Determination of temperature at which gutta percha becomes plastic.—This temperature depends almost entirely on the relative proportion of gutta and resin. The apparatus used by Obach consists of a rectangular frame in which three strips (Nos. 1, 2, and 3) of gutta percha are each held under the tension of a spring, it being so arranged that an electric contact is established and an alarm sounded as soon as one of the strips becomes soft enough to allow the spring to pull it apart. In a

certain experiment No. 1 contained $2\frac{1}{2}$, No. 2, 38, and No. 3, 60 per cent. of resin; No. 1 being artificially produced. The frame with the strips is immersed in water in a large beaker slowly heated on a sand bath. Up to 40° C. nothing occurs. At 42° C. the bells sound, and the shutter No. 3 of the indicator drops, which shows that No. 3 sample, containing 60 per cent. of resin, has sufficiently softened to yield to the spring. The bell rings a second time at 48° C. A rather long time elapses before the bell rings for the third time, before No. 1 shutter drops, and the strip No. 1, with $2\frac{1}{2}$ per cent. of resin, softens at 55° C.

Determination of temperature at which gutta percha softens.[1]—This has only a relative value, and depends on the particular method of testing employed. A thin plate of the gutta percha to be tested is placed in a large shallow water bath heated slowly over a gas burner. A rather long lever is supported at one end by a pivot, and carries a 1 lb. weight at the other. Half-way along the under side of the lever is fixed a vertical stud of 3 mm. diameter, and under this stud the gutta percha is placed from time to time to see whether any permanent impression is made. When such occurs, the temperature of the water is recorded as that at which the gutta percha begins to soften.

The action of heat, says Sherman, in softening gutta percha and making it plastic, has previously been used as a test of value. It has been found that the best grades require a higher temperature to soften them than the lower grades. According to the results obtained by him, an inferior grade of gutta also possessed the property of softening at a lower temperature than superior gutta. The softening point was determined by moulding a piece of gutta into the bottom of a glass tube sealed below, placing a sharp-pointed glass rod in contact with the surface, and gradually heating in a bath of sulphuric acid until the point of the glass rod just began to enter the gutta.

Determination of the temperature at which gutta percha becomes pliable.[1]—A strip of the gutta percha to be tested, about 70 mm. long, 25 mm. wide, and 2 mm. thick, is held vertically in a tall water bath. The upper end is provided with a clip, and to this a thin cord is fixed, which passes over a pulley and carries a half ounce weight at the other end. A definite pull being thus exerted on the strip, the temperature is observed at which this pull is just sufficient to tear it asunder.

Determination of the time of hardening of gutta percha.[1]—The time taken by the gutta percha to become sufficiently rigid to resist the pressure of the stud in the apparatus used for the softening temperature, but filled with water kept exactly at 75° F., the material, which is in the form of a 2 mm. plate, having previously been heated to the temperature at which it becomes pliable. The time of hardening is greatly influenced by the amount of resin in the gutta percha, and the variation with the percentage of resin can be represented by a continuous curve.

Action of atmospheric agents.—Exposed to air and to light, gutta percha undergoes rapid decay, due, to all appearance, to oxidation. It at the same time gives off a very acrid smell. This decay is more rapid when the substance is exposed to the air at a temperature of 25° to 30° C. (77° to 86° F.) in thin sheets or ribbons, and if it be moistened frequently and then left to dry in the sun. Gutta percha does not perish instantly in a stream of ozonised air, like indiarubber. It in this way becomes brittle, friable like rosin; it increases in weight and in solubility in alcohol and alkalies; and, finally, it becomes a good conductor of electricity, a property which it did not before possess. W. A. Miller and C. Hoffmann (*Annales de Chimie et de Pharmacie*, 215, 297) attribute this change to oxidation. The oxidised portion is insoluble in water and benzine; it only melts at 100° C. (212° F.). According to the above writers, all the gutta perchas of commerce contain it up to 15 per cent.

[1] Obach.

The following is, according to Miller, the composition of this oxidised resin :—

TABLE XCIX.—ANALYSIS OF OXIDISED PORTION OF GUTTA PERCHA.

	Per Cent.
Carbon	76·15
Hydrogen	11·16
Oxygen	12·69
	100·00

Gutta percha rendered brittle by oxidation in air and light may be reclaimed to be used for certain purposes if digested for some time in tepid water, and then kneaded again, but it soon cracks and becomes useless for any purpose. Its tendency to deteriorate in contact with air and light naturally greatly limits the industrial uses of this substance. K. M. Blossom (*Moniteur Scientifique de Quesneville*, iii. Series, t. ix. p. 240 *et seq.*) has summarised the works of Clark and W. A. Miller on the action of air and light on gutta percha. 32·35 grammes, say an ounce, of gutta in a thin sheet were successively submitted during eight months to the following conditions :—

(1) In a flask, open to the air, but protected from water; (2) in a flask, open to the air, but kept in the dark; (3) in soft water, in the open air, and exposed to light; (4) in soft water, in the open air, but protected from light; (5) in soft water, protected from air and light; (6) in salt water, in the open air, exposed to light; (7) in salt water, in the open air, but protected from light; (8) in salt water, protected from air and light. Samples (3), (4), (5), (6), (7), (8) underwent no change except a slight increase in weight, due to absorption of water. After being exposed to air for two hours they abandoned the water absorbed, and the tenacity and structure of the gutta percha were not altered. No. (1) which had been rolled up and run on into an inverted flask, with its mouth open, had absorbed 5 per cent. of oxygen, and a part of the mass (55 per cent.) was converted into resin. The outside layers exposed to light were resinous and brittle, but the interior portions, protected from light by the outside folds, were but little altered either in texture or appearance. No. (2) had suffered little or no change. It had increased ½ per cent. only in weight, and only ceded 7·4 per cent. of resinous matter to alcohol.

Another sample, only exposed to light for two months, had become brittle, had increased 3·6 per cent. in weight, and ceded 21·5 per cent. of resinous matter to alcohol, whilst another sample of the same sheet kept in darkness had undergone no appreciable modification. It thus follows that it is the oxygen of the air, aided by sunlight, which acts on gutta percha so as to profoundly modify its proximate constitution. The extent of the decay varies with the gutta percha itself. Every step taken to prevent oxidation is therefore a useful preventive against the destruction of the gutta percha. Thus Gerard has suggested as a preventive the incorporation of 10 to 12 per cent. of wax or tallow. But the only process hitherto known as of any use for preventing *resinification* consists in placing this substance under water. Practically it is indestructible therein, and there is not a single example of a submarine cable the gutta percha of which in its submerged part has suffered from the action of oxygen. Certain companies, therefore, enclose the subterranean lines, constituting the continuation of the submarine cables, especially in hot countries, in water pipes permanently filled with water, by means of reservoirs placed on culminating points of the ground. In dry conduits, where the cable is in contact with air, the gutta eventually shrinks up, becomes friable, and leaves the copper conductor exposed.[1] Edwin Clark found in 1852 that in the purifying gutta percha the latter unites, mechanically,

[1] A G.P.O. collection of short lengths of gutta percha covered wires which had been used in underground street cables, and showing numerous places where the gutta percha had perished, was used by Obach to illustrate his *Cantor Lectures.*—TR.

with a certain quantity of water, which, under the influence of the variations of temperature to which gutta percha is exposed during the process, partially evaporates, leaving a more or less porous resin. A good gutta percha, taken from a cable of recent manufacture, and analysed by Miller in 1860, contained 15 per cent. of resin and 2·5 per cent. of water. Although purification processes have been much perfected since then, it seems, from experiments made in 1876 by Professor Abel, that as regards the oxidised products produced at the expense of the gutta and the interposed water, no real progress had been made. A sheet of extra fine gutta percha yielded 12·7 per cent. of resin and 5 per cent. of water. These proportions varied respectively between 20 and 27·5 per cent. and 3 and 13 per cent. respectively, in seven other samples which he examined. Classifying them afterwards according to their commercial value, he found that there did not exist any direct relation between these values and the proportions of resin and water contained in the gutta perchas tested. The analyses of gutta perchas of superior quality exposed for

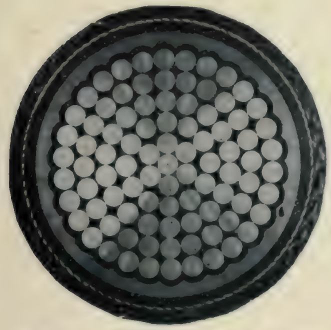


FIG. 118.—Single cable (Henley's). The figure illustrates a single cable conductor, 0·9 square inch area, insulated with one coat of pure Para rubber and two coats of vulcanising india-rubber to a thickness of 0·137 inch, taped, braided, and compounded, suitable for a working pressure of 660 volts; guaranteed minimum insulation resistance between the conductor and earth, 2500 megohms per mile.

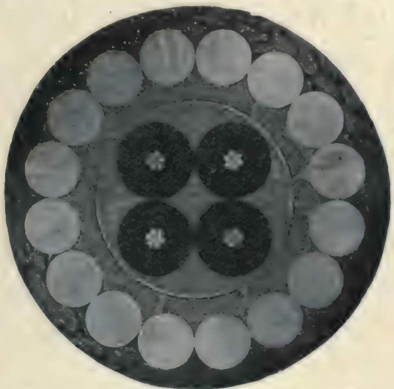


FIG. 119.—Section of Anglo-Belgian Telephone cable (four core submarine cable) constructed by Henley's. The figure illustrates a section of a four core submarine cable manufactured for the General Post Office (usually known as the Anglo-Belgian Telephone cable), and was laid between St. Margaret's Bay, England, and La Panne, Belgium. Total length of cable about 48 knots; weight of conductor per knot, 160 lb.; weight of gutta percha per core per knot, 300 lb.; thickness of gutta percha on each core, 0·145 inch; inductive capacity per knot, 0·275 microfarads.

several years to air and light show that oxidation caused thereby only proceeds slowly when the gutta percha has been rendered sufficiently compact by prolonged mastication. To prevent its decay, gutta percha has been varnished in the case of gun-impressions, and it has been suggested to treat it with a 4 per cent. solution of formaldehyde (in the case of museum specimens). The proportion of interposed water enables the approximate state which the sample has reached in this respect to be ascertained. Moreover, this transformation or oxidation does not take place in a constant manner, whilst certain articles resist all deterioration, other samples, submitted to the same condition, so far perish as to crumble to dust as soon as touched. This anomaly is easily explained, if we consider that the commercial gutta perchas used in the experiments are essentially of variable composition, and never come (we may boldly affirm) either from the same plant, or even from a mixture in identical proportions of different species of gutta perchas. The elementary compositions of these resins were studied by Hoffman and Miller, but their results do not agree.

TABLE C.—ELEMENTARY ULTIMATE COMPOSITION OF GUTTA PERCHA (HOFFMAN AND MILLER).

	Carbon.	Hydrogen.	Oxygen.	
Hoffmann . .	62·79	9·29	27·92	100·00
Miller . . .	76·15	11·16	12·69	100·00

Gutta percha is preserved indefinitely when immersed in water, more particularly in sea water Nevertheless, time finished by getting the better of this substance, unattackable by the chemical agents held in solution in sea water. Another enemy came to replace them, namely, the minute organisms which live in the sea. When a copper wire covered with gutta percha is laid on the bottom of the sea, it must be protected as shown in Figs. 120 and 121. The least injurious of the organisms which attack gutta percha is the *Teredo navalis.* The *Teredo navalis* is a sort of worm, of a greyish colour, belonging to the genera of *acephalous* mollusca, which sometimes attain 30 cms. (say a foot) in length. It is said that animals of the *teredo* genus attack gutta percha no further than to taste it, and facts would seem to affirm this assertion. During repairs to the Dover to

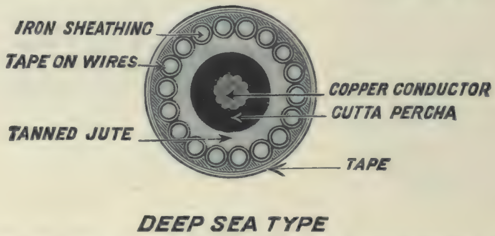


FIG. 120.—Submarine cable. Cross-section, showing arrangement, nature, and construction of the different layers.

Calais cable in 1851, it was found that the hemp had completely dissappeared in all those points where the corrosion of the iron was discovered; but the core was only perforated by two holes penetrating to the copper wire. But all the ends of the Dover to Calais experimental cable which have been brought up from the sea up to now have been found without the least trace of any animal attack whatever. Now this cable only consisted of a copper wire covered with gutta percha without any exterior protection whatever.

TABLE CI.—CLASSIFICATION OF SUBMARINE CABLES, LENGTH OF CORE, AND WEIGHT OF GUTTA PERCHA (OBACH).

No. of Group.	Description of Cables.	Approximate Length of Core.	Approximate Weight of Gutta Percha.
		Nautical miles (Knots).	Tons.
I.	Trans-oceanic	42,000	6,000
II.	Round coasts of America . . .	41,000	2,600
III.	Round east and west coasts of Africa .	18,000	1,200
IV.	Round coasts of Europe and Asia, and to Australia	83,000	6,200
	Total . .	184,000	16,000

The *Limnoria lignorum* or *tenebrans*, the most redoubtable enemy of gutta percha, is a small crustacean of the size of an ant, which easily slips between the narrowest interstices left between the wires of the armature, so as to get at the

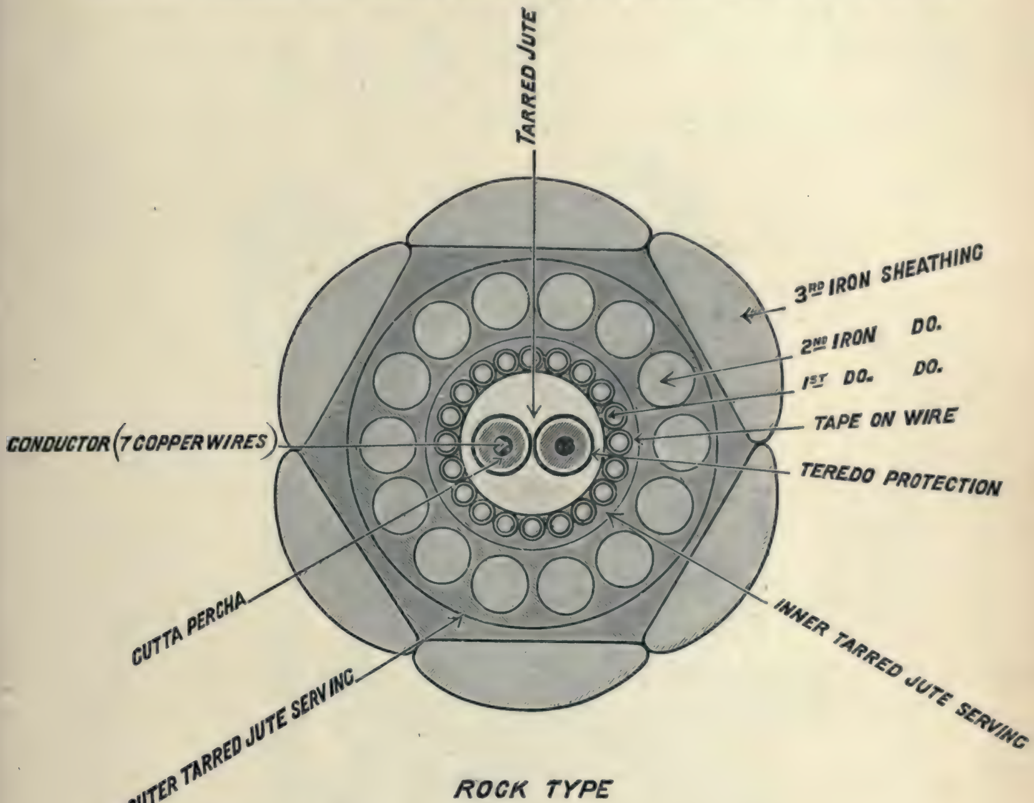


FIG. 121.—Submarine cable. Cross-section showing arrangement, nature, and construction of different layers.

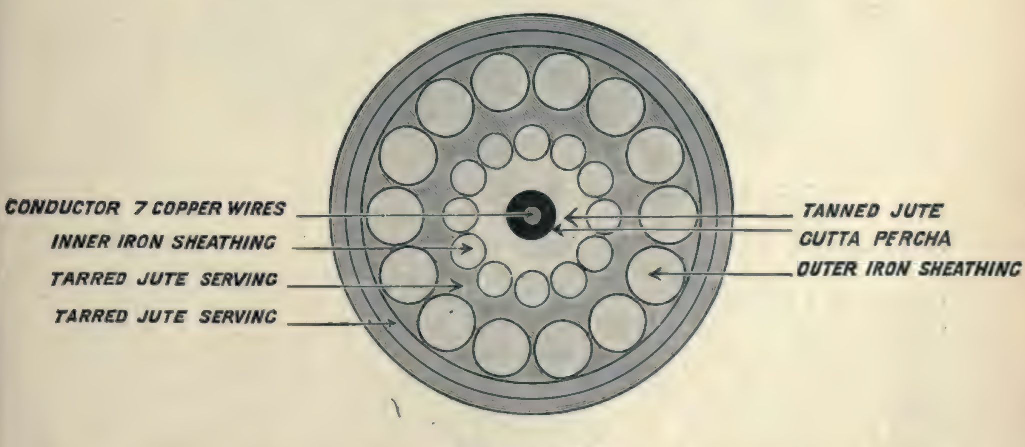


FIG. 122.—Submarine cable. Cross-section showing nature and construction of different layers.

core, which it perforates from point to point. Its head is armed with five or six pairs of hooks; its feet, like those of the lobster, are attached to the first six rings of its body. The latter likewise carries a pair.

On land gutta percha is still exposed to attack by other animals, *e.g.* rats, whose ravages in sewers are well known, and the *Templetonia cristallina*, a microscopic insect of the *Podura* family. The wires may be preserved by embedding them covered with gutta percha in cement. Like all hydrocarbides with a high coefficient, gutta percha is extremely inflammable, burns with a bright flame, emitting sparks, allowing a black residue to drop, after the manner

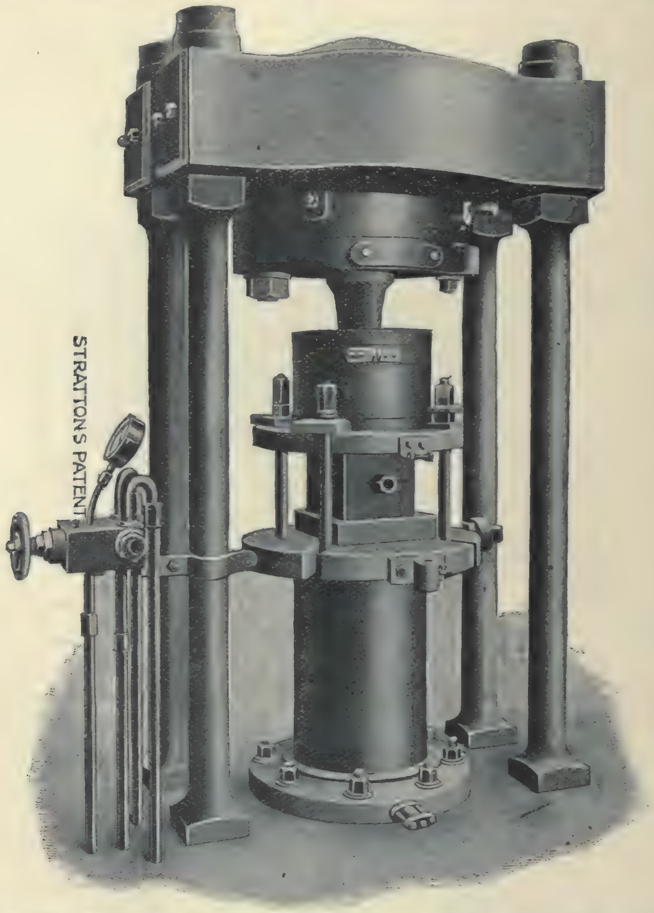


Fig. 123.—Lead press for covering electric cables and for making lead pipes.

of sealing-wax, which it resembles in the way it burns. It is a bad *conductor of heat*, but, as it is very impressionable under ever so slightly elevated a temperature, this property has not been utilised either by science or by industry. Gutta percha as an electrical insulator is likewise so bad a *conductor of electricity* that it is justly regarded as *the* dielectric plastic substance *par excellence*. It is rapidly electrified by rubbing, and the too brittle glass disc in electro-static machines was therefore replaced by one of gutta percha, equally good and much less fragile. Unfortunately, these discs, in time, as they resinified in contact with the air, split, and the advantage of the first few hours became a serious drawback. Rubbed with glass, wool, etc., gutta percha becomes *electro-negative*. However, according to Ries,

TABLE CII.—ANALYSIS OF GUTTA PERCHA ON THE CORES OF SOME EARLY SUBMARINE CABLES (OBACH).

Year of Manufacture.	Where Laid.	When Picked Up.	When Analysed.	Percentage Composition.				Ratio. $\frac{G.}{R.}$	Electrical Properties per Cube Knot.		When Tested.
				Gutta. G.	Resin. R.	Dirt. D.	Water. W.		Insulation.	Inductive Capacity.	
									Mégohms.	Micro-farads.	
1850	England—France (Dover—Cape Grisnez) . .	1875	1888	85·0	9·1	2·7	3·2[2]	9·3	645	...	1875 (1)
1853	Scotland—Ireland (Portpatrick—Donaghadee) .	...	1888	75·8	17·0	2·5	4·7	4·5	...	...	... (2)
1857	Ireland—Newfoundland	...	1897	76·1	20·3	3·0	0·6[3]	3·7	...	...	... (2)
1858	England—Holland	1897	1897	80·2	12·8	2·9	4·1	6·3	589	·0785	1897 (3)
1863	Persian Gulf	...	1888	75·7	17·1	2·7	4·5	4·4	1002	·0661	1865 (4)
1869	Black Sea	1882	1882	68·9	23·9	3·2[1]	4·0	?	2630	·0646	1882 (3)

(1) Willoughby Smith. (2) No data. (3) Obach. (4) Clark and Sabine.

[1] Possibly a litte too high, on account of Chatterton's compound between the layers.

[2] Another piece contained 4·2 per cent. aqua.

[3] Too low, owing to long exposure to air; another specimen gave 1·4 per cent. aqua.

when gutta percha, which has been left for some time exposed to the open air, and thus acquired a peculiar greyish blue coloration, is so rubbed, it becomes *electro-positive.* Freed from this coloured layer by washing with ether or spirits of turpentine, if rubbed with wool or glass it rebecomes *electro-negative*, whilst unwashed, in the same conditions, *electro-positive.* By rubbing gently with a piece of silk, sparks of 0·025 metre (say 1 inch) in length may be obtained. Faraday in 1843 was the first to point out the insulating property of gutta percha, and to forsee the application which might be made of this substance as a dieletric.[1] This remarkable property is not lessened, even in those atmospheric conditions, when glass becomes a good conductor. Sunk under water, and in the ground, in spite of deteriorating causes of all kinds of moisture, of mould, and even of insects, gutta percha preserves intact its highly remarkable insulating properties.[2] The *insulating power* of gutta percha, or the resistance which this substance presents to the passage of the electric current, measured relative to copper taken as unity, according to Wunschendorff, all dimensions being equal, at a temperature of 24° C. (75°·2 F.), is approximately 60,000,000,000,000,000,000 or—

$$6 \times 10^{19}.$$

An idea of the magnitude of this number may be got by remarking that light, the speed of which is about 77,000 leagues per second, would take longer than six thousand years to traverse the distance which this number would express in metres.

Obach demonstrated the two principal electrical properties of gutta percha experimentally. He took an electroscope with a flat brass disc at the top and two pith rods underneath, suspended on either side of a fixed strip of brass. A thin piece of gutta percha is spread over the brass disc like a tablecloth, and on charging the electroscope by aid of the brass knob at the side, the pith rods diverge and remain stationary. On laying the fingers on the top of the disc so that they are separated from it by the gutta percha tissue, the rods slightly converge and then remain stationary. On withdrawing the hand they again take up their former position. This simple experiment demonstrates simultaneously the two electrical properties of gutta percha. The fact that the hand (which through the body is connected with the earth) could be held on the upper side of the thin tissue for a considerable time without discharging the electroscope, shows its excellent insulating quality, and the binding of the electrical charge of the disc of the electroscope, indicated by the temporary partial collapse of the pith rods whilst the hand rests on the tissue, showing the inductive capacity of the gutta percha. The insulation should be as high as possible, and the inductive capacity generally as low as possible; but as the inductive capacity is generally accompanied by other good qualities in the gutta percha, etc., such is not always the case with a high insulation. Obach further points out that Faraday had some difficulty in 1848 in obtaining gutta percha with a sufficiently good insulation for his purpose, and he found that this was due to an excess of water in the commercial article. Obach demonstrated the effect of water in gutta percha on its insulating properties, by taking some strips containing about 15, 10, 5, and 2½ per cent. of water respectively. On charging the electroscope, and on touching the brass knob with the strip containing 15 per cent. of water, and on pressing the finger against the other side, the pith rods gradually converge, but as they do not regain their former position when the strip is removed, it shows that the charge has been dissipated by contact with the gutta percha. Repeating the experiment with the charge containing 15 per cent., the charge disappears much more slowly, whilst the 5 per cent. sample is found to be a good insulator, equal in fact to that with 2½ per cent. water. But different kinds of gutta perchas behave differently in that respect.

The different natural gutta perchas have different properties, and mix superior

[1] Obach gives the date of Faraday's researches as 1848, and those of Werner Siemens, who would thus have the prior claim, as 1846.

[2] Decaying organic matter also acts injuriously (Obach).

fibrous gutta perchas of greater durability and greater mechanical resistance with inferior guttas of considerably greater insulating capacity, and a less electro-static capacity. It results, therefore, that the insulating resistance and the specific electrostatic capacity of gutta percha, brought to unity of volume, varies between certain limits, and ought to be determined in each particular case. Moreover, the gutta perchas of commerce being mixtures of natural guttas, the makers of electric cables,

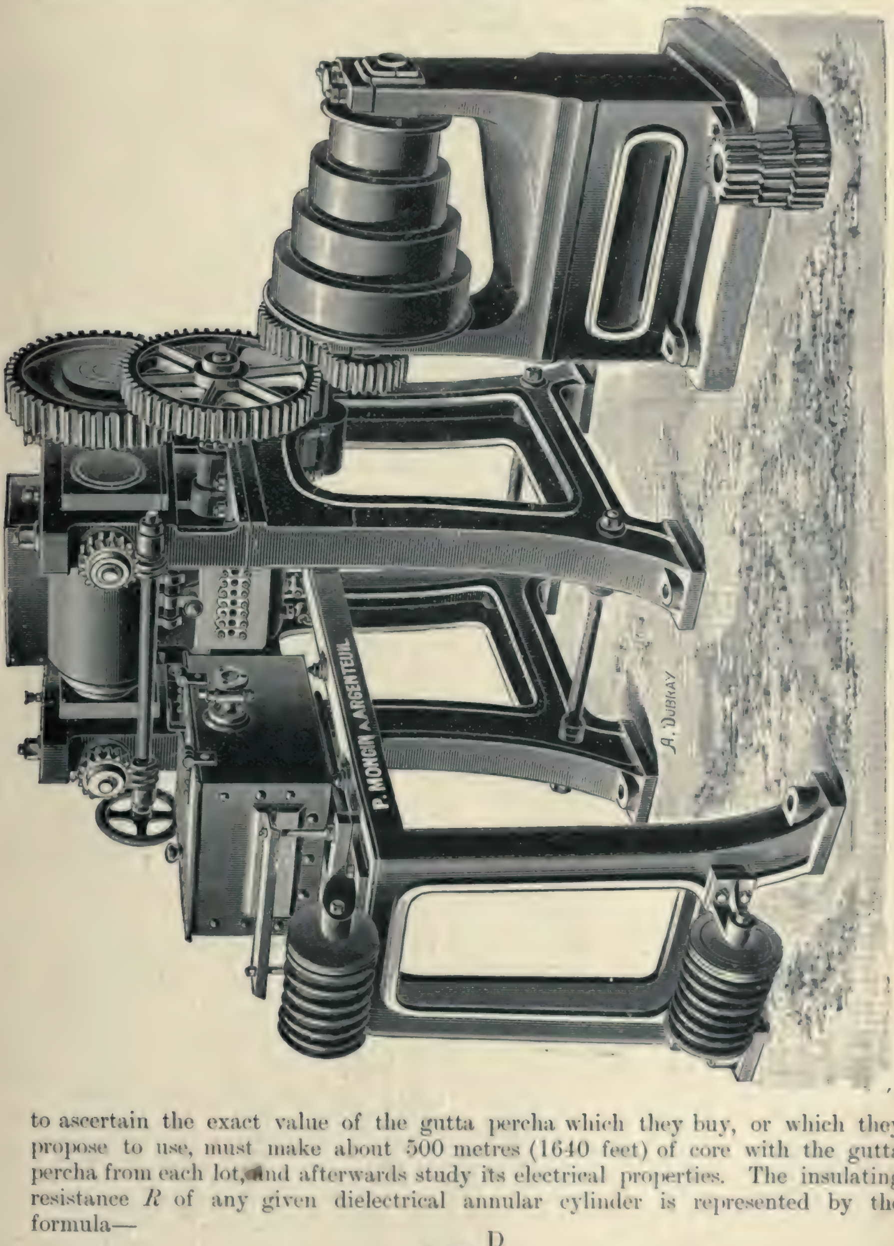


Fig. 124.—Machine for covering electric wires.

to ascertain the exact value of the gutta percha which they buy, or which they propose to use, must make about 500 metres (1640 feet) of core with the gutta percha from each lot, and afterwards study its electrical properties. The insulating resistance R of any given dielectrical annular cylinder is represented by the formula—

$$R = \frac{A \log \frac{D}{d}}{L}.$$

in which A indicates a constant, D and d the exterior and interior diameters of the cylinder, L its length. For a gutta percha cable we get approximately per knot—

$\mathrm{R} = 750 \log \frac{\mathrm{D}}{d}$ megohms, at the end of a minute of electrisation, and after twenty-four hours' immersion in water at 24° C. (75°·2 F.). With recently made cables, the value of A may be less than two-thirds of that given above. The insulating resistance of gutta percha diminishes as rapidly as the temperature rises. The law of variation is represented by the formula—

$$\frac{\mathrm{R}}{r} = \mathrm{A}t$$

in which R and r respectively represent the lowest and the highest of the two temperatures the difference of which is t degrees and A a constant. The coefficient A should be determined for each quality of the gutta percha of commerce. If t be expressed in °C., the value of A for average quality gutta is about 0·87604. We then get—$\log \mathrm{R} = \log r + \log 0{\cdot}87604$. Table CIII. affords an idea of the variation of the resistance of gutta percha at different temperatures, but cannot be applied with any precision to any and every species of gutta percha (J. Munro A. Jamieson's *Pocket Book*, 1885). Pressure increases the resistance of gutta percha :

TABLE CIII.—VARIATIONS IN THE RESISTANCE OF ORDINARY GUTTA PERCHA AT DIFFERENT TEMPERATURES (MUNRO).

Temperature.		Relative Resistance.	Logarithms of the Resistance.	Temperature.		Relative Resistance.	Logarithms of the Resistance.
°F.	°C.			°F.	°C.		
32	0·0	23·622	1,373,317	67	19·4	1·801	0,255,516
33	0·5	21·947	1,341,375	68	20·0	1·673	0,223,496
34	1·1	20·391	1,309,439	69	20·5	1·555	0,191,730
35	1·6	18·945	1,277,495	70	21·1	1·444	0,159,567
36	2·2	17·602	1,245,562	71	21·6	1·342	0,127,753
37	2·7	16·354	1,213,624	72	22·2	1·247	0,095,867
38	3·3	15·995	1,181,701	73	22·7	1·158	0,063,709
39	3·8	14·117	1,149,742	74	23·3	1·076	0,031,812
40	4·4	13·116	1,117,801	75	23·8	1·000	0,000,000
41	5·0	12·188	1,085,861	76	24·4	0·9418	1,973,959
42	5·5	11·322	1,053,923	77	25·0	0·8870	1,947,924
43	6·1	10·520	1,022,016	78	25·5	0·8354	1,921,895
44	6·6	9·774	0,990,072	79	26·1	0·7867	1,895,809
45	7·2	9·081	0,958,134	80	26·6	0·7410	1,869,818
46	7·7	8·437	0,926,188	81	27·2	0·6978	1,843,731
47	8·3	7·839	0,894,261	82	27·7	0·6572	1,817,698
48	8·8	7·283	0,862,310	83	28·3	0·6190	1,791,681
49	9·4	6·767	0,830,396	84	28·8	0·5829	1,765,594
50	10·0	6·287	0,798,444	85	29·4	0·5490	1,739,572
51	10·5	5·841	0,766,487	86	30·0	0·5171	1,731,575
52	11·1	5·427	0,734,560	87	30·5	0·4870	1,687,529
53	11·6	5·042	0,702,603	88	31·1	0·4586	1,661,434
54	12·2	4·685	0,670,710	89	31·6	0·4319	1,635,383
55	12·7	4·353	0,638,789	90	32·2	0·4068	1,609,381
56	13·3	4·044	0,601,811	91	32·7	0·3831	1,583,312
57	13·8	3·757	0,574,841	92	33·3	0·3608	1,557,267
58	14·4	3·491	0,512,950	93	33·8	0·3398	1,531,223
59	15·0	3·244	0,511,081	94	34·4	0·3000	1,505,150
60	15·5	3·013	0,478,999	95	35·0	0·3014	1,479,143
61	16·1	2·800	0,447,158	96	35·5	0·2839	1,453,165
62	16·6	2·601	0,415,140	97	36·1	0·2674	1,407,161
63	17·2	2·417	0,383,277	98	36·6	0·2518	1,401,051
64	17·7	2·245	0,351,216	99	37·2	0·2371	1,374,932
65	18·3	2·086	0·319,314	100	37·7	0·2233	1,348,889
66	18·8	1·938	0,287,354				

if we indicate by r its resistance to atmospheric pressure, by R its resistance to the pressure p expressed in kilogrammes per square centimetre, we get—$R = r(1 + 0{\cdot}00327\ p)$. The specific electro-static capacity of gutta, relative to that of air, taken as unity, is about 4·2. The capacity C of an annular cylinder of exterior and interior diameters D and d is expressed by the ratio—

$$C = A \frac{L}{\log \frac{D}{d}}$$

L representing the length of the cylinder; A being a constant. For a gutta percha cable we get *approximately* per marine mile—

$$C = \frac{0{\cdot}18769}{\log \frac{D}{d}} \text{ microfarads.}$$

The constant 0·18769 varies with the quality of the gutta percha.

Relative resistance (after a minute of electrisation) *at different temperatures of ordinary gutta percha as cores in which the thickness of the gutta percha does not exceed* 2·79 *millimetres* ($\frac{1}{14}$ of an inch) (Willoughby Smith).

The weight of gutta percha necessary to obtain a core of diameter D, with a conductor of diameter d, D and d both being expressed in millimetres, is about—

$$1{\cdot}43\ (D^2 - d^2) \text{ kilogrammes.}$$

Dielectric Strength—An important electrical property, which has recently come into prominence, is what is called the *dielectric strength* or resistance to piercing by high voltages. Table CIV. gives the dielectric strength of various gutta percha-covered wires (cores), and the corresponding thickness of the insulating material or *dielectric*; it also gives for comparison the dielectric strength of caoutchouc-covered wires and of ebonite. A thickness of a little over $\frac{1}{8}$ inch of gutta percha breaks down with 40,000 volts, and one of about $\frac{1}{10}$ inch with 28,000 volts.

TABLE CIV.—COMPARATIVE DIELECTRIC STRENGTH OF GUTTA PERCHA CAOUTCHOUC AND EBONITE (OBACH).

Nature of Dielectric.			Thickness of Dielectric in decimals of an inch.	Voltage at which Dielectric broke down.
GUTTA PERCHA—	Copper per knot lb.	G. P. per knot lb.		
Cores of various sizes from Submarine Cables.	500	320	0·127	40,000
	450	280	0·109	28,000
	107	150	0·0925	18,000
	107	130	0·0825	15,000
	130	130	0·0805	14,000
Test cores made from	Pahang		0·051	19,000
	Banjer Red		0·058	20,000
	Bulongan Red		0·048	19,000
	Bagan Soondie		0·049	15,000
	Serapong Soondie		0·054	18,000
	G. P. from leaves		0·047	17,000
CAOUTCHOUC—				
Core of Overland Telegraph Cable			0·102	20,000
Core of Submarine Cable			0·078	19,000
EBONITE (Sheet)—			0·130	38,000

Action of solvents.—Gutta percha resists most solvents. It is completely *insoluble in cold water*, softens in boiling water and in steam; it none the less remains quite entire, whatever may be the temperature of the water vehicle, and is preserved almost unalterable therein. Gutta percha, however, swells in boiling water, and absorbs about 5 to 6 per cent., which it afterwards only parts with slowly when left to itself. But if it be heated to 150° C. (302° F.) in the swollen hydrated condition, it rapidly abandons its interstitial water without undergoing any constitutional change. It is almost insoluble in cold weak alcohol, its solubility augments with the increase of alcoholic strength and on heating, and if it be boiled in absolute alcohol, it loses about 15 to 20 per cent. of oxidised resinous bodies. If *ether only dissolves a small quantity of gutta percha* (Payen), it *dissolves completely* therein provided the ether be absolutely pure, *i.e.* free from alcohol (Arpe). Ether containing even a small quantity of alcohol loses the property of completely dissolving gutta percha. It dissolves partially in hot spirits of turpentine, shale oil, olive oil, and, better still, in benzine. The best solvents are carbon disulphide and chloroform. These solvents do not cause it to swell like rubber. Solution takes place gradually from the surface to the interior. The cloudy liquids so obtained, after filtration, become perfectly limpid and colourless. By evaporating the solvents, the *pure gutta percha* so obtained has the appearance of virgin wax. Hot solutions deposit gutta percha in clots on cooling: alcohol precipitates it from this solution, but the precipitated product often retains traces of the solvent used, especially benzine between its pores, which renders it tacky.

Action of reagents—Gutta percha bottles alone stand hydrofluoric acid.—Concentrated alkaline solutions, dilute acid, even hydrofluoric acid itself, are without action upon gutta percha, and it was the researches of Staedeler on this point (published in the *Annales de Chimie et de Pharmacie*, lvii. p. 137), which gave birth to the gutta percha bottle industry for the transport and storage of fluoric acid in the liquid state. Concentrated sulphuric acid dissolves gutta percha, colouring it brown, and disengaging sulphurous acid. Nitric acid attacks it, producing nitrous fumes, and, according to Oudemans, the products of the reaction consist of formic and hydrocyanic acids. Very concentrated hydrochloric acid likewise attacks it eventually. According to Berthelot[1] (*Bulletin de la Société Chimique*, 1869, xi. p. 33), one part of gutta percha, as pure as possible, heated to 280° C. (536° F.), with 80 parts of hydriodic acid, produces complete hydrogenation of the substance. It yields saturated carbides (paraffins), boiling at a very high temperature.

Having examined the product of this reaction, Berthelot ascertained that it did not contain any hydrocarbide volatile at a low temperature, nor any carbide volatile below 360° C. (688° F.). It is a viscous matter, rather similar to fused rubber, which obstinately retains interposed water. When heated it swells much, and in an explosive manner, as the water is being disengaged. But the water, in evaporating, does not carry along with it any volatile hydrocarbide. When the water is entirely eliminated, the temperature may be raised to 350° C. (662° F.) without any carbide distilling, and it is only by still furthur raising the temperature that it finally distils, but without undergoing apparent decomposition. The carbide thus obtained presents the reactions of the formenic carbides (paraffins): resistance to bromine, to fuming and cold nitric acid, to fuming and lukewarm sulphuric acid.

Chemical composition.—Commercial gutta percha, even when absolutely pure, is not a simple substance the elementary principles of which one can study forthwith. It consists of several proximate principles in more or less variable proportion, according to its botanical origin and the different manipulations it has undergone. It is therefore impossible to examine its chemical composition before demonstrating (1) the method of preparing chemically pure gutta percha, and the process (2) of separating its known proximate principles. Payen commenced the preparation of the pure substance by dissolving raw gutta percha in carbon disulphide, filtering and evaporating it in the air on a marble or glass slab without

[1] See Preface to second English Edition for translator's justification of the chemical terminology used here.

amalgam. After complete desiccation, the plates of purified gutta percha are detached and covered with cold water, which stops the tackiness in a few moments: 100 parts of gutta percha so treated gave the following results (Miller):—

TABLE CV.—RESULTS OF ANALYSIS OF GUTTA PERCHA BY PAYEN'S METHOD (MILLER).

	Per cent.
Purified gutta percha	79·70
Resins	15·10
Vegetable fibre	2·18
Water	2·50
Ash	0·52
	100·00

From a gutta percha so purified Arpe extracted seven different resins, which presented perceptible variations in solubility in ether, and in alcohol of different strengths and temperatures. Arpe gave formulæ for the composition of these resins which, moreover, are absolutely hypothetical, as saline compounds of these resins which would enable their atomic weight to be fixed are unknown. Payen, by treating gutta percha, purified as above by cold alcohol, then by boiling alcohol, has shown that there existed therein three quite distinct proximate principles in the following average proportion:—

1. *Gutta* (insoluble in cold alcohol and in boiling alcohol), 78 to 82 per cent. 2. *Fluavile* (insoluble in cold alcohol), 4 to 6 per cent. 3. *Albane* (soluble in boiling alcohol), 14 to 16 per cent. To isolate each principle, the purified gutta percha is treated for several hours with boiling alcohol, and filtered. The alcoholic solution deposits, after standing for one or two days, an abundant granulation of white opalescent matter, forming a nucleus, soluble in absolute alcohol (amorphous yellow substance), whilst the exterior envelope is insoluble, and becomes more and more white and diaphanous. By repeatedly washing the granulated mass with cold alcohol, the fluavile is dissolved, whilst the albane remains insoluble. After having repeatedly boiled the gutta percha in alcohol, there remains the chemically pure substance called by Payen *gutta*.

Obach hardens gutta percha by dissolving it in petroleum ether, and then cooling to 60° F. The gutta, or hardened gutta percha, is precipitated whilst the albane, fluavile, etc., remain in solution (see p. 386).

TABLE CVI.—CHEMICAL, PHYSICAL, MECHANICAL, AND ELECTRICAL PROPERTIES OF HARDENED GUTTA PERCHA (OBACH).

	G.	R.	D.	W.	$\frac{G}{R}$	Softens, etc., at ° C.	Pliable, etc., at ° C.	Hardens in minutes.	Tensile Strength (lb. per sq. in.).	Elongation (per cent.).	Insulation (in megohms).	Inductive Capacity (microfarads).
A	54·7	39·4	2·7	3·2	1·4	37·7	58·8	17	1592	360	34,970	·0613
B	93·0	2·8	2·5	1·7	33·2	57·2	91·1	$\frac{3}{4}$	5662	285	27,410	·0575
C	97·3	1·2	0·3	1·2	78·5	58·3	94·4	$1\frac{1}{2}$	6757	380	6,640	·0471
D	94·1	1·2	2·0	2·7	78·4	60·5	90·0	1	5937	425	10,030	·0608
E	94·9	0·8	2·2	2·1	120·0	61·6	93·3	1	5008	265	8,350	·0588

A = Medium quality cleaned in ordinary way; B = same material hardened by extracting the resin; C, D, E, various other materials hardened by extracting the resin.

Fluavile is a yellowish diaphanous resin, a little heavier than water; it is hard and brittle at 0° C. (32° F.), softening towards 50° C. (122° F.), becoming pasty at 60° C. (140° F.) [at 42° C. (105·6° F.) according to Oudemans], and completely fluid at 100° to 110° C. (212° to 230° F.). It is decomposed at a higher temperature into different badly defined hydrocarbides. It is soluble in the cold state in alcohol, ether, benzine, spirits of turpentine, carbon disulphide, chloroform. When the solvents evaporate, amorphous fluavile is deposited. It resists dilute and concentrated acids and alkaline liquids, but is rapidly destroyed by sulphuric and nitric acids. Its composition was determined by Oudemans (*Rep. de Chimie appliquée*, 1858–59, p. 455). It yields [1]—

Table CVII.—Elementary Composition of Fluavile (Oudemans).

	I.	II.
	Per cent.	Per cent.
Carbon	83·36	83·52
Hydrogen	11·17	11·42
Oxygen	5·47	5·06
	100·00	100·00

and thus corresponds with the formula $C_{20}H_{32}O$. Fluavile is thus simply an oxidation derivative of gutta.

Albane is a white crystalline lenticular resin; examined under the microscope, it appears as diaphanous radiated follicles. It is heavier than water, only melts at 160° C. (320° F.) [140° C. (284° F.), Oudemans]; not acted on by hydrochloric acid. It is soluble in benzene, spirits of turpentine, carbon disulphide, ether, chloroform, and boiling anhydrous alcohol. 100 parts of cold alcohol dissolve 5·1 parts and 54 parts on boiling. It crystallises out on cooling from its solutions. The following is its composition:—

Table CVIII.—Elementary Composition of Albane. (Oudemans).

	I.	II.
	Per cent.	Per cent.
Carbon	78·87	78·95
Hydrogen	10·58	10·31
Oxygen	10·55	10·74
	100·00	100·00

which corresponds with the formula $C_{20}H_{32}O_2$. Heated to 130° C. (266° F.), it is changed into $C_{20}H_{30}O$. When the boiling alcohol which has been used to extract the gutta percha is allowed to cool, it deposits white rounded granulations, consisting of a nucleus of fluavile, covered with a crystalline incrustation of albane, which may be separated from each other by means of cold alcohol.

Gutta, the principal element of commercial gutta percha, is solid, pliant, extensible, but not elastic between 10° and 30° C. (50° and 86° F.). It softens about 45° C. (113° F.), and begins to assume a deep brown coloration. As the

[1] Obach, agreeing with Oudemans, found for albane C. = 78·96, H. = 10·58, O. = 10·46, but for fluavile C. = 80·79, H. = 11, O. = 8·21, or $C_{40}H_{64}O_2$, which neither agrees with Oudemans nor with Osterle, who found $C_{40}H_{64}O_2$ for albane and $(C_{10}H_{16})n$ for fluavile, thus reversing Oudemans' results.—Tr.

heat increases, it becomes more viscous and transparent. At 100° to 110° C. (212° to 230° F.) it spreads out into a soft paste, and liquefies at 130° C. (266° F.), and then commences to "boil," yielding on distillation several hydrocarbides analogous with those yielded by the distillation of rubber. The property of *pure gutta*, of becoming plastic at higher temperatures, shows that it is not a simple body, but a mixture (alloy) of several hydrocarbons, differing probably only in their molecular constitution. The case is similar to that of the tinman's solder in the state in which it is used for making what is technically called a "wiped joint." In presence of acids, dilute alcohol, ether, and chloroform, gutta behaves like gutta percha.[1] Gutta, unless previously treated with alcohol (Arpe), is not insoluble in ether. Heated with nitric acid, it gives off formic and hydrocyanic acids. Reduced to powder, it rapidly absorbs oxygen; gaseous hydrochloric acid transforms it into a brownish black substance, which contracts on its surface and presents the appearance of a fused substance. Its instability is very great, and it is difficult to preserve intact except in a solution of common salt. Soubeiran was the first to analyse gutta, but he did not succeed in completely separating the albane from the fluavile.

TABLE CVIIIA.—ELEMENTARY COMPOSITION OF GUTTA (SOUBIERAN).

	Per cent.
Carbon	83·5
Hydrogen	11·5
Oxygen	5·0
	100·0

TABLE CIX.—ELEMENTARY COMPOSITION OF GUTTA (OUDEMANS)

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Carbon	87·64	88·10	88·20
Hydrogen	11·79	11·77	12·0
Oxygen	0·57	0·13	...
	100·00	100·00	100·20

The composition of gutta would thus correspond with the formula $C_{20}H_{32}$ or C_5H_8 (Oudemans). Baumhauer confirmed Oudemans' results as to the elementary composition of gutta, albane, and fluavile. According to him, pure commercial gutta percha would consist essentially of a hydrocarbide $C_{20}H_{32}$, identical with the gutta of Oudemans and with several oxidation products of the same substance. Baumhauer exhausted commercial gutta percha, previously washed with water and hydrochloric acid, either by ether, which abandons the gutta as a white pulverulent substance, or by dissolving the substance in chloroform, and pouring the solution into alcohol, which precipitates the gutta in flocks, which are purified by careful washing with boiling absolute alcohol. Miller's formula for gutta would be $C_{20}H_{30}$, but the pure commercial gutta percha contains a hydrocarbide, $C_{20}H_{32}$, mixed with different oxidation products, $C_{20}H_{32}O$ and $C_{20}H_{32}O_2$ (Oudemans). The relations which may exist between the latter products and the products of the spontaneous and

[1] Pure *gutta* is insoluble in ether and light petroleum spirit at the ordinary temperature, whereas albane and fluavile dissolve readily in these menstrua. Obach's so-called "chemical hardening process" consists simply in extracting the resin from the gutta percha by means of light petroleum spirit extraction plant on a large scale.—TR.

ultimate oxidation of gutta [1] are unknown. On distillation, gutta is decomposed in the same way as rubber. C. Greville Williams has separated the following hydrocarbons: iosoprène, caoutchine, and hévéène, in the following proportions :—

TABLE CX.—DESTRUCTIVE DISTILLATION PRODUCTS OF GUTTA PERCHA (GREVILLE WILLIAMS).

	Per cent.
Caoutchine	20
Isoprène	5

During distillation a volatile acid is given off, which Blossom regards as one of the lower members of the series $C^nH^{2n}O_2$. We may thus regard pure caoutchouc and pure gutta (the unoxidised principle of gutta percha) as two isomeric compounds of the same series. According to Blœkrode, *Palaquium* juice contains but one and the same principle, namely, gutta. The different substances which are found therein arise exclusively from the deterioration it undergoes during collection, which explains the difference found in the qualities of the products now imported which are undoubtedly superior to those imported a few years ago, when the process of tapping the trees was unknown, and felling alone was in vogue.

Physical and chemical properties of gutta percha, called yellow gutta, of the Straits Archipelago (botanical origin,—Payena Lerii, Mayang Sundek).—Ed. Heckel and L. Schlagdenhauffen made a comparative study of the gutta perchas of the *Palaquiums*, and the gutta perchas produced by (1) the *Payenas*, (2) the *Mimusops*, and (3) the *Bassias*. Some extracts from their patient researches will be useful, even if their conclusions cannot always be accepted, but discussion spreads light; and light on such a subject as the present one is very necessary.

(1) *Payena Lerii.*—The samples analysed had the form of a hard yellow mass, easily scratched by the thumb-nail, softening more than Mimusops guttas (to be referred to later on), and adhering more strongly to the hand, which softened them by its warmth. They uniformly assume the garb of round balls of 150 to 200 grammes (say 5 to 7 ounces), somewhat uneven and flattened in certain points, which gives them a striking resemblance to a freshly peeled potato. By treating the substance with boiling alcohol, a yellow tacky liquid is obtained, which, after spontaneous evaporation, leaves small needle-shaped crystals. By working on 5 grammes only, 1·5 grammes remained, consequently 3·5 grammes were dissolved in the alcohol.

Alcoholic extract.—Fifty grammes of raw material yielded 35 grammes of extract, which, taken up by petroleum ether, yielded a tacky portion soluble in the vehicle, with silky, almost colourless, crystals. The crystals so obtained are insoluble in water, soluble in alcohol, ether, chloroform, benzine, carbon disulphide; they do not act on litmus, melt at $+65°$ C. (149° F.), and yield, on cooling, a hard, transparent varnish. It resists fused potash. Concentrated sulphuric acid colours it brownish yellow, passing eventually to violet. Nitric acid attacks it even in the cold, and very violently at the temperature of the water-bath. The reaction neither yields oxalic nor picric acids. The composition of the crystalline substance, according to their analysis, is as follows :—

TABLE CXI.—ULTIMATE ANALYSIS, CRYSTALLINE BODY, FROM PAYENA LERII, GUTTA PERCHA (HECKEL AND SCHLAGDENHAUFFEN).

Carbonic acid	0·4615 whence C	67·930	per cent.
Water	0·2175 ,, H	12·083	,,
Difference	O	19·987	,,
		100·000	

[1] Otto Osterle found a fourth substance, *guttane*, in gutta percha, yielding, after several precipitations from its chloroformic solution by alcohol, C. = 86·4, H. = 12 per cent.—TR.

hence the formula $C_5H_{10}O$. The tacky matter mentioned above is found in the mother liquor of the crystals. Preserved and exposed to variations of temperature from $-5°$ to $+18°$ C., it remains perfectly limpid. Analysis shows almost complete identity with the crystalline product, even in regard to solubility in different menstrua, with the exception of petroleum ether, which completely dissolves it, whilst it scarcely acts upon the crystals: the same red coloration with sulphuric acid, the same decomposition with nitric acid, the same resistance to the action of fused potash. Applied (in chloroformic solution, or dissolved in petroleum ether) on glass, wood, or any other hard body, it may replace varnish. But its elementary composition is not the same. The authors only found in it 49·635 of carbon instead of 67·930, and 11·305 of hydrogen in place of 12·083. It therefore contains much more oxygen. From its physical properties it might at the outset be taken for *fluavile*, but its molecular composition is completely different. The substance which remains after the extraction of the raw material by absolute alcohol, possesses, according to the authors, all the qualities of an excellent caoutchouc. It may be drawn into thin threads, and springs back on itself, on account of its great elasticity. According to Heckel and Schlagdenhauffen, the yellow gutta of the Straits Archipelago is merely a mixture of 30 per cent. of gutta and of two resins, the one crystallisable and the other tacky.

(2) *Physical and chemical properties of Abyssinian gutta extracted from the Mimusops Schimperi et Kummel* (of Hochst).—The samples analysed were received from a M. Jambert, of French origin, who had become Menelik's Minister at Shoa. The substance was a hard brown mass, of not so dark a colour as the *Palaquium* gutta of commerce. Easily scratched with thumb-nail, it softened slightly in the hand, and became tacky, although heat did not make it tackier. The authors first treated the substance with tepid water, then with boiling water, to separate as far as possible the vegetable débris and other impurities which it contained. By cooling the liquid afterwards, and stirring it vigorously, they fixed on the stirrer a more or less elastic substance of the same colour, entirely different from the non-adherent granular deposit at the bottom of the dish. In spite of repeated treatment with hot water, they were not able to agglutinate this latter portion. The cause of its resistance to plasticity is due to the considerable quantity of fixed salts contained in the deposit, since an analysis of 0·627 of substance gave 0·127 of ash. The deposit which falls to the bottom of the water contains therefore—

Table CXII.—Analysis of Abyssinian Gutta.

	Per cent.[1]
Organic matter	72·54
Ash	27·44

The adherent elastic matter of an earthy brown colour was kneaded between the fingers until a homogeneous mass was obtained. In appearance this mass is rather analogous with ordinary gutta percha. It softens in water, but always preserves considerable elasticity. Owing to these defects, in can never be substituted for good commercial gutta percha without previous modification and transformation. Numerous attempts to eliminate or minimise these drawbacks were unsuccessful. Sudden variation of temperature and pressure gave negative results. As a last resource, attempts were made to mix the gum with ordinary gutta percha, with the hope that the excess of elasticity and adhesiveness might be masked by the plasticity of the better quality gutta percha Two mixtures containing Abyssinian gutta were made and sent to the printing-works of Berger, Evrault, to ascertain if the new product might find an industrial use, and be capable of being

[1] The figures given by the authors calculated to per cent. give 79·74 and 20·26 respectively.—Tr.

used for taking impressions of the moulds of blocks for steel engravings used in making galvanos. The answer was prompt: the experiment gave excellent results. To ascertain the cause of so marked a difference between these two varieties of gutta percha, the authors (H. and S.) tried to find out how they behaved in presence of different chemical reagents. The first experiments were naturally with such solvents as alcohol, ether, carbon disulphide. Now, whilst alcohol does not dissolve ordinary gutta percha, the Abyssinian substance dissolved therein to the extent of 42 per cent. The boiling solution is colourless. On cooling, a white mamillated, but non-crystalline, product is deposited. The microscope shows some rare needles, which cannot be eliminated by any of the vehicles successively employed for this purpose. The authors conclude that the substance is amorphous, with a tendency to crystallisation. By repeated solution in boiling alcohol, it was at last obtained of a snow-white colour. The compound, of a fusible nature, melts at 107° C. (224·6° F.). Heated to 230° C. (446° F.), it remains liquid without the least alteration, but at a higher temperature it turns brown and decomposes. It dissolves in ordinary alcohol, wood spirit, acetone, benzene, chloroform ether, spirits of turpentine, petroleum ether, and carbon disulphide. It does not dissolve in boiling potash, and does not yield double decomposition products by the action of fused potash. Nitric acid attacks it very energetically — a crystalline body, oxalic and picric acids, and other substances, being produced. Its formula is C_5H_8O or $C_{20}H_{32}O_4$. It may therefore be considered as an oxidation product of *albane*, $C_{20}H_{32}O_2$, contained in ordinary gutta percha, but it differs from it in its chemical properties. Moreover, it does not possess any of the characteristics of *fluavile*, $C_{20}H_{32}O$, which accompanies the *albane* of ordinary gutta percha. These two resins, the former of which is white and crystallisable, the other amorphous and translucid, are associated with the *gutta*—

Table CXIII.—Proximate Analysis of Organic Portion of Abyssinian Gutta.

	Per cent.
Gutta	75·82
Albane	19·14
Fluavile	6·14
	101·10

whilst the *mimusops gutta* percha only contains the white non-crystalline resin of which we have given the analysis, and which amounts to 42 per cent. of the raw product. The remainder, *i.e.* 58 per cent. of matter insoluble in alcohol, forms a dark-coloured substance, the appearance of which recalls that of ordinary gutta, and, like it, it is soluble in ether, and completely insoluble in ordinary alcohol, wood spirit, and acetone. The product contains 9·8 per cent. of fixed residue, consisting almost solely of sulphate of lime. The composition of the *mimusops* gutta percha may therefore be put down as—

Table CXIV.—Composition of Mimusops Gutta Percha.

	Per cent.
Gutta	48·20
Fixed salts	9·80
Amorphous resin	42·00
	100·00

The raw product, as well as the gutta purified by the previous elimination of the whole of the resin, or, better still, by only a portion of that resin, may be utilised as we have said. *To obtain the most suitable compound for the making of galvanos*, they boil the substance with its own weight of 90 per cent. alcohol, filter and incorporate the cake, which remains in equal proportions with ordinary commercial gutta.

(3) *Physical and chemical properties of the gutta percha extracted from the Bassia Parkii or gum of the Karité tree—Density.*—The density of this product is 0·976, whilst Payen assigns to the crude gutta percha of the *Palaquiums* that of 0·975. *Insulating properties.*—It becomes electrical by rubbing as easily as the latter, and may therefore be likewise used as an insulator. It softens in hot water in the same way as commercial gutta, and becomes adhesive like it at a temperature bordering on ebullition. From a chemical point of view, however, some differences exist. *Action of solvents.*—For the two products do not behave in an identical manner with solvents. Bassia gutta treated with petroleum ether, ordinary ether, spirits of turpentine, and boiling acetic acid, cedes to these solvents a less amount of soluble principles than ordinary gutta. Moreover, the evaporated solutions do not leave identical products. The residues of the Bassia gutta are tacky, whilst those of commercial gutta consists, so to speak, of a dry, non-adhesive varnish. Identity is almost complete, from the point of view of solubility, in carbon disulphide, chloroform, benzene, and cold and boiling alcohol. With the two first solvents, only an insignificant insoluble residue remains of quite a black colour, provided always that a sufficient quantity be taken. As to the solvent power of benzene, it is likewise similar. The insoluble residue is identical in the two products, but a little more pronounced than in the former instance. As to the solubility in 95 per cent. alcohol, it is equal in both instances, but this latter solvent only dissolves 7 per cent. of the substances treated. Summing up the solvent powers of the different vehicles, and bringing the results to per cent., we get the following Table :—

TABLE CXV.—SHOWING THE SOLUBILITY OF ORDINARY GUTTA PERCHA AND BASSIA GUTTA PERCHA IN DIFFERENT SOLVENTS.

	Carbon Disulphide.	Chloroform.	Benzine.	Ordinary Ether.	Petroleum Ether.	Spirits of Turpentine.	Acetic Acid.	Alcohol 95 per cent.
Commercial gutta percha . . .	99·72	98·68	93·20	40·8	34·0	20	19·2	7
Bassia gutta percha .	97·92	92·28	92·80	20·1	18·1	8	12·8	7

TABLE CXVI.—SHOWING, BY PAYENS PROCESS, THE COMPARATIVE PROXIMATE COMPOSITION OF CRUDE AND PURIFIED COMMERCIAL GUTTA PERCHA AND BASSIA GUTTA PERCHA.

	Crude Commercial Gutta Percha.		Crude Bassia Gutta Percha.	Commercial Gutta Percha No. 1 Purified by Carbon Disulphide.	Bassia Gutta Percha Purified by Carbon Disulphide.
	I.	II.			
Gutta . . .	92	91·5	91	92	91·5
Albane . . .	6	6·5	5·5	5·8	6·0
Fluavile . . .	2	2	3	2·2	2·3
	100·0	100·0	99·5	100·0	99·8

By heating these two gutta perchas until carbonised, and incinerating the product, ashes of similar appearance were obtained—

TABLE CXVII.—SHOWING THE COMPARATIVE AMOUNT OF ASH IN BASSIA GUTTA PERCHA AND COMMERCIAL GUTTA PERCHA.

	Residue in Grammes.		Per cent.
10 grammes of Bassia gutta left	0·120	=	1·20
10 ,, of commercial gutta percha . . .	0·126	=	1·26

Spectrum analysis gave sodium, potassium, and lithium. There is almost complete identity. Summing up:—The products of the *Mimusops* approach in composition and properties true *Palaquium* gutta percha, whilst the *Payena* seem more allied by their composition and chemical properties with caoutchouc. Both products are much further away in their nature from real gutta percha than the *Bassia Parkii* product, whose identity with *Palaquium* is nearly complete. Although the conclusions of scientific chemists and professors cannot always be accepted, and, until a new order of things and proof to the contrary is forthcoming, it may be safely asserted that the gutta perchas of the *Payena Lerii* are powerful and almost indispensable adjuncts in the making of mixtures of industrial gutta perchas, we have nevertheless not hesitated to reproduce this research almost in its integrity. Comparative researches of this nature alone enable the truth to come soon to light, to the great profit of commerce and industry. The opinions on the products of *Bassia Parkii* require more ample information. If their scientific data should have to be recognised as exact, and the Ghée tree should really have to be regarded as capable of yielding a utilisable gutta percha, it would be an urgent matter to undertake its rational culture as promptly as possible. It would then, without doubt, be one of the most useful trees of tropical Africa, the more so as this plant loves dry gravelly soils, and, moreover, it is extremely hardy. We could then apply to it the term applied to the *Manihot Glazowii* with respect to caoutchouc: the *Bassia Parkii* would be the gutta percha tree of the future.[1]

Obach is not so enthusiastic as Heckel. From the samples at his disposal he formed an unfavourable opinion of Bassia gutta. He says:—The solid oil or fat of the shea butter-tree, which is largely used for soap-making, contains from 0·5 to 0·7 per cent. of a hydrocarbon said to be similar to gutta, and which has been termed "gutta shea." I have examined a specimen of the concrete milk from the trunk of the tree; also some of the gutta from shea butter, and some slightly fermented gutta from the trunk, which I received in 1891. They were taken from samples sent to the Kew Museum from Western Africa some years ago by Sir George Goldie, of the Royal Niger Company. Two of the samples con-

TABLE CXVIII.—ELEMENTARY ANALYSIS OF BASSIA GUTTA PERCHA BY FENDLER.

	I.	II.	III.	Calculated for $C_{10}H_{16}$.
Carbon . . .	86·93	87·07	87·29	88·14
Hydrogen . . .	10·93	10·98	11·21	11·86

[1] Serrulaz and Hourant (British Patent, 654; 1896) claim the extraction of gutta from the raw material of *Bassia Parkii* by toluene and subsequent precipitation by acetone just as they extract ordinary gutta from the leaves.—TR.

tained about 14 per cent. of a substance somewhat resembling gutta, but possessing no strength or tenacity, and partaking more of the nature of a wax. The material could, therefore, hardly replace gutta percha, except, perhaps, for some special application. However, I should not like to express a definite opinion on this substance until I have examined it in a perfectly fresh and intact state.

Bassia gutta yields potassium cinnamate on saponification with alcoholic potash. Oxygen containing bodies are also present.

TABLE CXIX.—ANALYSIS OF SIX SAMPLES OF BASSIA GUTTA COLLECTED BY VON KERSTLING IN LAMA.

	1.	2.	3.	4.	5.	6.
	Per cent.	Per cent	Per cent.	Per cent.	Per cent.	Per cent.
Gutta . . .	25·61	19·8	19·0	21·2	15·0	17·7
Resin . . .	50·5	78·5	65·0	76·0	74·5	56·0
Ash . . .	7·01	0·80	5·2	0 6	6·5	7·8

1, Old latex ; 2 and 3, fresh latex preserved by ammonia ; 4, fresh latex, water added, and preserved by ammonia ; 5, fresh latex preserved by ammonia. Fresh latex air dried.

Balata—Physical and chemical properties.—In the preceding research, Heckel and Schlagdenhauffen, have referred to Abyssinia gutta, a product of *Mimusops Chimperi et Kummel*, but not to the product of the *Mimusops Balata et Globosa*, put on the market under the name of balata. The latter substance, besides its great strength, possesses the property of being slightly elastic when it is pulled, a property of great importance in the manufacture of transmission belts ; and it was this property which made Stagneri, an American manufacturer of rubber goods, declare that balata was the best rubber in the world. This substance would find a more and more extended consumption if a sufficient supply were put on the market ; but as matters stand its production is very limited. Its price is equal to if not higher than that of gutta percha, and that is the best proof that industry knows how to use it. In the generality of cases where gutta percha is utilised, balata is capable of usefully replacing it, and it is only its relatively high price which confines it to certain special uses. The manufacturing trade regards balata as a gutta percha, and one of the best ; once wrought up, its generic name would disappear, to be confused with the other sorts of industrial gutta perchas. Nevertheless, the product is far from being the same from a physical and chemical point of view. It is softer at the ordinary temperature, and remains pliant at low temperatures. The gutta contained in balata is very strong and tough, being altogether of excellent quality ; but the percentage of resin is a large one, and the material can consequently only be regarded as a substitute for second, or perhaps even third-class gutta percha. Balata is somewhat more flexible than gutta percha, containing an equal amount of resin, which appears to be due to the softness of the resinous constituents. (Obach had several times observed an oily substance exuding from balata on stretching, which, after drying up, left a whitish powder behind, resembling mildew). A loss in weight, usually observed during analysis, indicates the presence of volatile constituents. To determine the composition of the resin contained in balata, a specimen extracted with ether was carefully heated by Obach until the weight remained constant, whereby it lost 4·6 per cent. ; it was then repeatedly treated with boiling alcohol, from which the albane was precipitated on cooling as a white crystalline powder, leaving the fluavile in solution. It was then found that the resin consisted of about two parts of *albane* and three parts of *fluavile*.

Some of the specimens of balata sent to this country perished quickly when exposed to air and light, and this rather prejudiced the manufacturers against the material ; but others retained their good qualities a long time, and a sheet of

balata, which was manufactured in January 1881, nearly seventeen years afterwards, was still as sound as one could wish it. The sheet had been kept in a comparatively cool cellar, but without any special precautions. Obach was inclined to think that the materials which decayed so prematurely had either been carelessly prepared from the latex, or else were obtained by some special method of coagulation. The behaviour of balata towards atmospheric oxygen is referred to in the sequel.

If the commercial substance be purified by washing with boiling acidulated water, then by boiling alcohol, a residue remains, which, dissolved in carbon disulphide, filtered and evaporated, gives a similar composition to gutta, *i.e.*—

Carbon	88·5 per cent.
Hydrogen	11·5 ,,
	100·0 ,,

The colour of balata is reddish white, with dark spots and veins. It has no taste, and, when heated, emits the same agreeable odour as pure gutta, when slowly heated, under a layer of water and gradually brought to the boiling-point. Its specific gravity is 1·05. It may be cut like gutta percha, but it has much greater tenacity.

TABLE CXX.—ANALYSIS OF VARIOUS HISTORICAL SAMPLES OF BALATA (OBACH).[1]

No.	Percentage Composition.				Totals.		Ratios.		Percentage Composition.	
	Gutta.	Resin.	Dirt.	Water.	Balata. G. + R.	Waste. D. + W.	Balata. / Waste.	Gutta. / Resin.	Gutta.	Resin.
(1)	43·2	40·3	14·5	2·0	83·5	16·5	5·1	1·1	51·7	48·3
(2)	47·4	43·6	8·3	0·7	91·0	9·0	10·1	1·1	52·1	47·9
(3)	43·3	41·6	13·0	2·1	84·9	15·1	5·6	1·0	51 0	49·0
(4)	44·5	41·6	12·2	1·7	86·1	13·9	6·2	1·1	51·7	48·3
(5)	41·1	42·6	14·1	2·2	83·7	16·3	5·1	0·97	49·1	50·9
(6)	42·6	48·0	3·7	5·7	90·6	9·4	9·6	0·89	47·0	53·0
(7)	31·1	27·0	4·3	37·6	58·1	41·9	1·4	1·2	53·5	46·5
(8)	52·4	39·8	5·3	2·5	92·2	7·8	11·8	1·3	56·8	43·2
(9)	43·5	36·9	14·3	5·3	80·4	19·6	4·1	1·2	54·1	45·9
(10)	41·5	34·8	9·9	13·8	76·3	23·7	3·2	1·2	54·4	45·6

	Analysed.
(1) Berbice (Dr. Van Holst), 1860 .	1886
(2) British Guiana (Intern. Exh.), 1862	,,
(3) ,, (James Collins), 1868	,,
(4) Trinidad (J. R. Longden), 1874 .	,,
(5) Demerara (E. F. M. Thurm), 1882 .	,,
(6) ,, (J. S. Jenman), 1884 .	,,
(7) Demerara (J. S. Jenman), 1886 .	1897
(8) British Guiana (Col. & Ind. Exh.), 1886	,,
(9) Surinam (Tubergen & Daam), 1896	,,
(10) Mostly British Guiana (various) Importers, 1889–94 * . .	1889–94

* Average of ten commercial lots representing 50 tons.

Action of solvents and reagents.—Spirits of turpentine, and more especially benzine and carbon disulphide, dissolve it completely in the cold state. It withstands caustic alkalies like gutta percha and rubber, likewise hydrochloric acid. But sulphuric acid attacks it, carbonising it. Nitric acid transforms it into hydrocyanic and formic acids. If Balata resists acids less energetically, Rousseau rightly attributes this fault to the balata being always impure and charged with putrescible milky juices. Examined by the polariscope, balata, like gutta percha, exhibits in a very high degree the beautiful phenomenon of prismatic decomposition of colours, especially after having been strongly pressed. But what essentially differentiates balata from gutta percha is the way it behaves under the action of

[1] A sample with $\frac{G}{R}=1·16$ had a density of 0·9715 (Obach).

atmospheric agents. We know the transformations which gutta undergoes in contact with light and the oxygen of the air: its surface resinifies rapidly, and it is transformed into a dry, brittle substance. This transformation penetrates from the surface into the interior of the blocks, and the whole very soon perishes. It is not so with balata, which, under similar influences, resists their destructive action admirably, and for a long time.

Insulating properties.—As to the insulating resistance of balata, the authors assign to it an average specific resistance, and allow it to take a high place in the series of commercial gutta perchas. At the ordinary temperature it rather resembles a horny substance; it softens even at 49° C. (120·2° F.), and can then be made to assume any shape, or receive any imprint.

If in Table CXX. two specimens are disregarded, says Obach in valuing the balata from his analysis, there is not very much difference between the other ones as far as the ratio between pure gutta and resin is concerned, the quality q varying only between 4^a and 5, $q = \frac{r}{10}$. The larger amount of water which the commercial materials enclosed in comparison with the other specimens, is partly to be explained by the circumstance that the former were mostly analysed shortly after they arrived in London, whereas the other specimens had been in museums for many years before the analysis was made. The quality of the commercial balata as represented by Nos. 8, 9, and 10, is superior to that of any of the special samples 1 to 5. (The quality is expressed by dividing the percentage of resin by 10, fractions of a per cent., $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ being represented by a, b, c, see Table XCV.)

TABLE CXXI.—BALATA COLLECTED IN AND EXPORTED FROM BRITISH GUIANA, 1885–96.

	1885.	1886.	1887.	1888.	1889.	1890–91.	1891–92.	1892–93.	1893–94.	1894–95.	1895–96.	Total.
Cwts.	496	606	723	2219	3245	2025	1039	2120	1832	1867	1424	17,596
£	2113	2979	3498	14,069	15,652	10,078	6807	11,296	8283	11,484	8923	95,182
Per lb. in pence	9·13	10·54	10·37	14·17	10·34	10·66	14·05	11·42	9·69	13·18	13·43	Av. val. per lb. 11·59

CHAPTER VI

MECHANICAL TREATMENT OF GUTTA PERCHA

Like rubber, but more so, commercial gutta percha which comes to market contains, in greater or less quantities, a certain number of impurities, such as sand, soil, wood, bark of trees, either fraudulently added by the collector with a view to fraud, or because the imperfection of the available collecting processes did not allow him to do better. Before employing it for any purpose, gutta percha must be purified and freed from all sorts of inert matter, which might give rise to serious inconvenience during the ulterior transformations which the substance has to undergo. These purification processes are very simple, but rather numerous: manufacturers do not use them all, and, according to the nature of the raw material and special exigencies, one or more operations may be eliminated. Thus, in the making of different laboratory apparatus, it is possible to dispense with almost all the processes of purification, whilst in the making of submarine cable dielectrics we cannot multiply too many times the method of purification. Inspired by the researches of Heinzerling, Siemens, Wunschendorff, Obach, and Bobet, we shall follow step by step all the purification processes.

Preliminary work.—Operations are commenced by dividing the crude gutta percha into rather small fragments by a play of knives, or by a circular saw, but not without having previously softened the gum in a little hot water: for this purpose many factories still use at the present day the cutting machine patented by Hancock in 1847, No. 11,575. Fig. 127 shows a front view (I.), a side elevation (II.), and a section along a line *a b* (III.). This machine is nothing other than a kind of turnip slicer, the principal organ of which consists of a circular cast-iron or hard wooden plate or disc *B B*, mounted on the frame *A A*. The plate is pierced by three slots, in one part of which are inserted, like the cutting-iron of a plane or spokeshave, three radial knives, slightly inclined and projected slightly on the plane of the plate. The latter turns on the end of a shaft *B*, driven by a belt from a steam-engine or by any other gearing. The speed is regulated as required, and generally the plate makes 200 revolutions a minute against the sides of a cast-iron inclined table *D*, which serves as a hopper. When the machine is in motion, the lumps of crude gutta percha fall down an inclined shoot against the knives, by which they are cut into slices, corresponding to the degree of projection given to the knives, and fall into a receiver beneath. If the gutta percha to be shredded is harder than usual, the flat knives are replaced by more curvilinear blades, which cut it up better. Then commences the series of successive operations which are to transform the raw gutta percha into *normal gutta percha.*

The fragments in the receiver are freed by hand (hand-picked) from the coarser substances present. They are then collected, placed in an iron tank filled with hot water, which a steam coil maintains at the right temperature, and in which a mechanical agitator is constantly kept revolving. A part of the impurities falls to the bottom of the tank, the pieces of softened gutta percha float to the top, agglomerate into a compact mass, which is fished out by a perforated metallic shovel, and carried to the mincing machines and washers. Hancock was the first to invent a well-conceived arrangement for conducting these operations system-

atically. British Patent, 11,550, 10th February 1847. T (Fig. 128) is a large reservoir divided into three compartments t^1 t^2 t^3. The water level in the compartments t^1 t^2 is higher than in the compartment t^3. Three rolls, F^1 F^2 F^3, turn transversely to the reservoir and above the level of the water. These rolls are fitted with a great number of blades and circular saws with alternate teeth. In front of these crushing rolls are a pair of fluted feed rolls. The softened gutta percha from the table H^1 is fed into the pair of fluted feed rolls F^1. H^2 is an endless web rolling round two cylinders; the lower part dips into the compartment t^1, whilst the upper part communicates with the crushing roll F^2. A second endless web H^3 is arranged similarly, to bring the material to the crushing roll F^3. The mincing cylinder K is similar to the machine which in paper mills is used to shred rags. It is fitted with blades all over its circumference, and turns around an arrangement of edge plates fitted with similar blades. These are so fixed that the blades of the cylinder shall in revolving come into such close

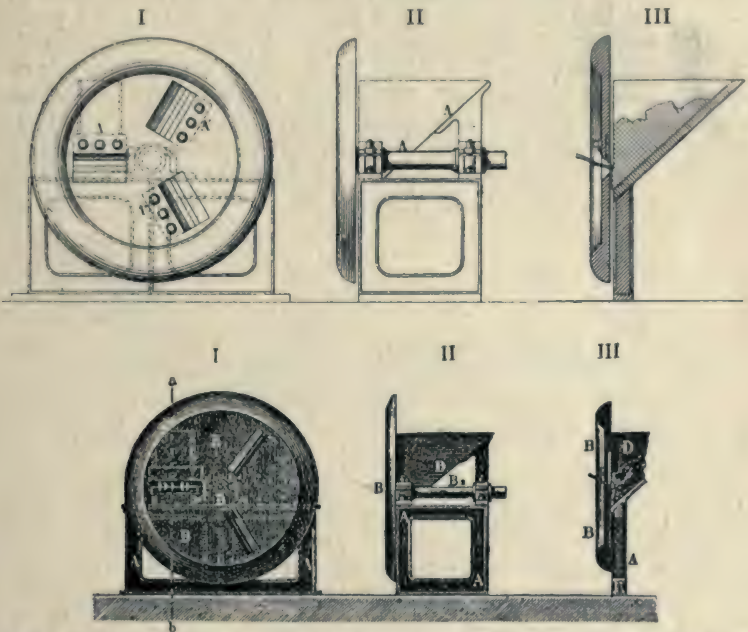


Fig. 125.—Machine for cutting up raw gutta percha (*slicing machine*) (Hancock's system).

parallelism with them as to produce, by their approximate conjunction, a scissors-like bolt of action. This mincing roll is so fixed as to be opposite the bottom of the rolls F^1 F^2 F^3, and is always half immersed in the liquid of the compartment t^3. The two series of blades of the mincing roll act like scissors, and do not leave a particle intact that comes in contact with it. The mincing roll K is likewise provided with an endless web H^4, and two feed rolls. M is a rotary mechanical agitator, wholly immersed in the water of the tank. Finally, a revolving endless web N, dipping to the bottom of the tank, divides the compartment t^3 into two sections. The second section of this compartment is fitted with a series of rollers R R R, mounted over this after-part of the tank, so that the under rollers revolve in the water and the upper just free of it. Under each of these set of rolls is a bench or table. The feed rolls, the rolls connected with the endless webs, and the rolls R R, move round from left to right, whilst the crushers F^1 F^2 F^3, the mincing cylinder K, and the rotary agitator M, move in an opposite direction. The speed of the crushing rolls and the mincing cylinder should be equal to about 600 to 800 revolutions a minute; whilst that of the feed rolls

and the endless webs should only be driven at a speed six times less. The first series of rollers *R R* need only turn at a speed of fifteen to twenty turns a minute, whilst the last pair may revolve at a great speed, so as to give more tension to the substance. The first crusher F^1 reduces the raw gutta percha to small fragments, and thus eliminates a considerable quantity of earthy matter and other extraneous substances. The whole falls into the water of the compartment *H*. There the particles of pure, or almost pure, gutta percha float, whilst the impurities fall to the bottom of the tank. The endless band H^2 seizes hold of the floating gutta percha, brings it to the feed rolls of the second compartment, and causes it to pass into the second crusher F^2. The gutta percha coming from the surface of the water of the compartment t^2 is carried by the endless web H^3 to the feed rolls, then to the crusher F^3, and is thus crushed a third time so as to free it from all impurity. The web H^4 seizes it and brings it to the mincing cylinder *K*, revolving at full speed, where it is ground into extremely finely divided fragments, and from which it falls into the liquid in the compartment t^3. The rotary agitator *M* beats it continually in the water and finishes the purification. The revolving endless web *N* conveys the purified gutta to the rollers *R R R*. From the last of these rollers it is taken by an endless web *O* to a pair of metal pressing and finishing rollers Y^1 Y^2, set to the size required, where it is laminated and freed from all interstitial water. Passing over the topmost of these rollers Y^2, and over a wooden drum *U*, it is wound on the taking-up roller *V*. Contrary to certain authors, the water in the tanks should always be cold; if the gutta percha should have an abnormal smell, which is very often the case,

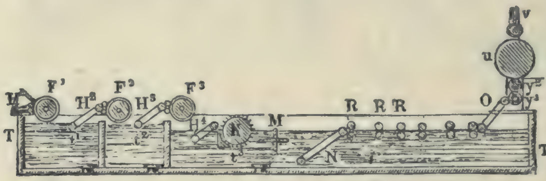


FIG. 126.—Section of breaking, mincing, and rolling machine and washers (Hancock's system).

it would be prudent to add a little bleaching powder. According to Maigne, there is another process having some analogy with the preceding. After having cut the lumps with a constantly moistened circular saw into irregular prisms, these prisms are submitted to a mincing machine like the preceding, with blades and circular saws with strong alternate teeth, on which a dribble of water constantly flows. The pulp thus obtained is washed three times in cold water, in the same number of vats, through which it is passed in succession, and where it abandons foreign bodies, some dissolved in the liquid, the others in suspension, or fallen to the bottom. As it is issues from the last vat, the pulp is well cleansed. It is then spread on a pavement or on a sloping asphalt floor, where it is left to drain, after which it is passed five or six times between the two cast-iron cylinders of a set of rolls. These hot rolls are 1 metre (3·28 feet) long and 40 centimetres (15·7 inches) in diameter, and are heated internally by a current of steam, and continually moistened on the outside. They deliver the gutta percha in the form of a consistent paste. The rolls are then adjusted so as almost to come in contact, so that they can only pass but a very small quantity of purified gutta percha between them. They are then put in motion. This fresh rolling converts the paste into very thin sheets. Two workmen seize each sheet as it issues from the rolls, then, by a regulated pull, they stretch it so as to double its width, whilst at the same time they remove any small particles of wood or bark remaining in the paste, which are then readily seen. The sheets thus produced being thin, dry rapidly in the air. When they have lost nearly all their water, they are placed in a shallow pan, heated by a steam coil to 100°

to 115° C. (212° to 239° F.). By the action of this temperature they are completely dried, and moreover they begin to enter into a pasty fusion, which cements all their parts.

Another process employed more recently in Hancock's factory.—The cuttings, obtained from the cutting-up machine, are run into an iron tank filled with water, and heated to the boiling-point. The agitation produced by the steam from the steam pipe facilitates the washing of the gum, and frees it from its impurities. A mechanical agitator, in motion, greatly assists in the work. The heat softens the gutta percha, which agglutinates in the form of irregular balls. These are placed in a larger cylindrical wrought-iron tank, in which there is a drum, fitted with bent toothed claws, touching the periphery of the cylinder. The drum makes 800 revolutions in a minute, tears the gum into threads of extreme tenuity, which a current of water carries into a vat fixed below the tank. Owing to its low specific gravity, the gutta percha floats, and the impurities fall to the bottom. The floating shredded gum is again softened in water of 95° C. (203° F.), in which it agglutinates, and is again passed through the masticator. Instead of mechanical shredding, recourse has also been had to solvents such as carbon disulphide, benzine, chloroform, etc., as purifying agents. The gutta percha, softened in the solvents, is introduced into the body of a pump, with very resistant sides, in which a piston moves up and down. The bottom of this cylinder is furnished with a diaphragm of perforated plates, such as are used in the hydraulic presses of vermicelli works. These plates are arranged in such a manner that the calibre of the holes diminish from the top plate to the bottom, the meshes of which are more numerous.

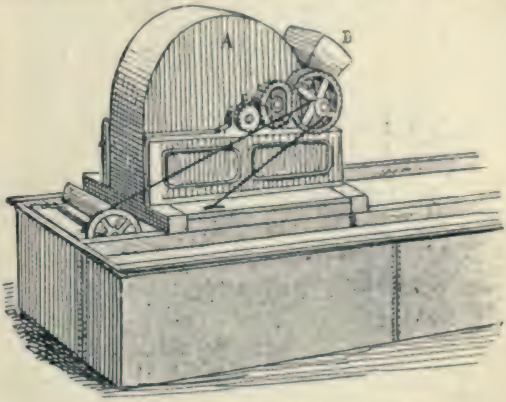


FIG. 127.—Slicing machine or chopper.

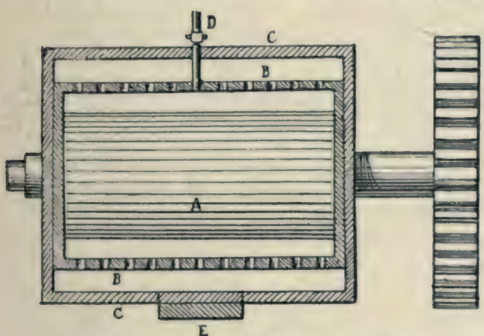


FIG. 128.—English washing machine (after Wunschendorff).

Instead of softening gutta percha by solvents, it has also been proposed to proceed to purify it by first softening it by the action of heat, and then passing it in that condition into a filter press like the preceding. The jacket which surrounds the cylinder enables the latter to be heated by steam, and too soon cooling of the gum is in that way prevented. This system of purification is utilised to complete the washing of the gum to be purified. According to Wunschendorff, the following is the method adopted in English factories in the purification (properly so called) of gutta percha:—The *slicing machine* (Fig. 127) consists of a cast-iron drum *A*, on the periphery of which are inserted knives with steel saw-teeth. This drum makes 500 revolutions a minute. The pasty mass of gutta which is fed into the hopper *B* passes between two small rolls *C* and *D*, the one with a smooth, the other with a striated surface, which leads them under the drum *A*, the knives of which shred it into small pieces.

These pieces fall into a large iron tank full of cold water, beaten by an agitator, with paddles always in motion. The gutta remains there for two or three hours, and is freed from a fresh quantity of its impurities; it floats, whilst the extraneous substances sink to the bottom of the reservoir. After being cleaned in this way, the gutta percha is run into a tank of boiling water, and when it is sufficiently soft, it is washed thoroughly in a special machine called a *washing machine.* A solid cylinder *A*, the surface of which is covered with grooves, turns inside a hollow cylinder *B*, pierced with holes, and itself enclosed in a hollow cylinder *C*.

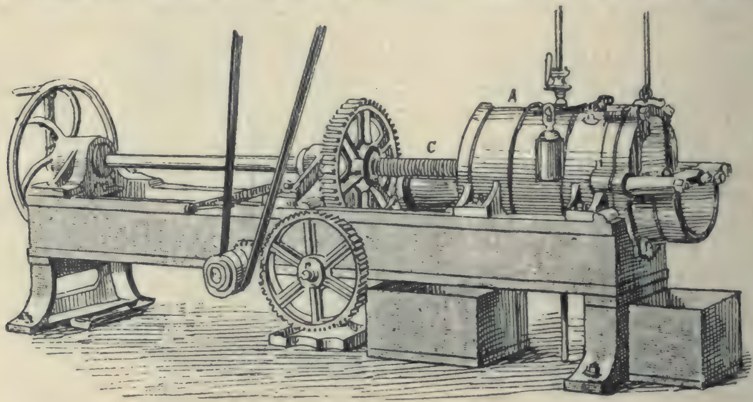


FIG. 129.—Filter press (strainer), English system (after Wunschendorff).

The gutta percha is placed between the grooved cylinder and the cylinder *B*; the interior of the two annular cylinders is filled with water heated by a steam jet from the small pipe *D*. The rotation of the grooved cylinder compresses the gutta percha against the cylinder *B*, and forces it to spread out. All the portions of the gutta percha thus come successively in contact with the hot water, which removes the impurities from them. These collect at the bottom of the cylinder *C*, and are removed by the door *E*. Gutta percha treated in this way most generally contains only very small-sized particles of organic débris, which it is preferable to free it from by a purely mechanical operation. Too prolonged washing with water has the disadvantage of incorporating a certain amount of water with the gutta, which it is afterwards very difficult to completely eliminate. This purely mechanical intervention is accomplished by means of the filter press (*strainer*), already described. The plant employed in England consists of a very thick cast-iron cylinder *A*, open at one of its ends, and in which a piston moves *B* (Figs. 129 and 130), of which the rod *C* is submitted to the action of a hydraulic press, which receives from a horizontal shaft, by means of a toothed wheel, gearing with a screw part of the rod, a very slow movement of translation towards the bottom of the cylinder. This cylinder is closed with a strong iron plate, pierced with holes, on which is placed a sheet of wire gauze with very close meshes. The sides of the cylinder are hollowed (jacketed), and filled with steam, to prevent the gum from solidifying. The cylinder being filled with the gutta percha to be purified, pressure is applied to the piston, the substance is pressed, and forced to pass through the wire gauze, and is collected in the receiver beneath the cylinder. When the piston is 1 or 2 centimetres from the bottom, the motion is stopped, and the cake in which all the impurities are collected is withdrawn. Mongin, of Argenteuil, has constructed a filter press (Fig. 131) built on the same principle.

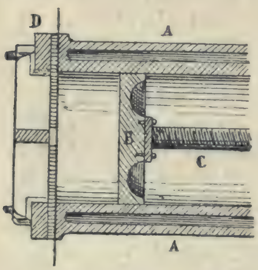


FIG. 130.—Piston of above filter press (strainer).

Gérard's process.—A much simpler purifying process was proposed and put in practice by G. Gérard, which he says answers well. It consists in simply treating the crude gutta percha with the shredder used for rubber. Only, instead of cold water, hot water is employed. If the process would accomplish the end in view, it would evidently be the best, but there is every reason to doubt its efficiency.

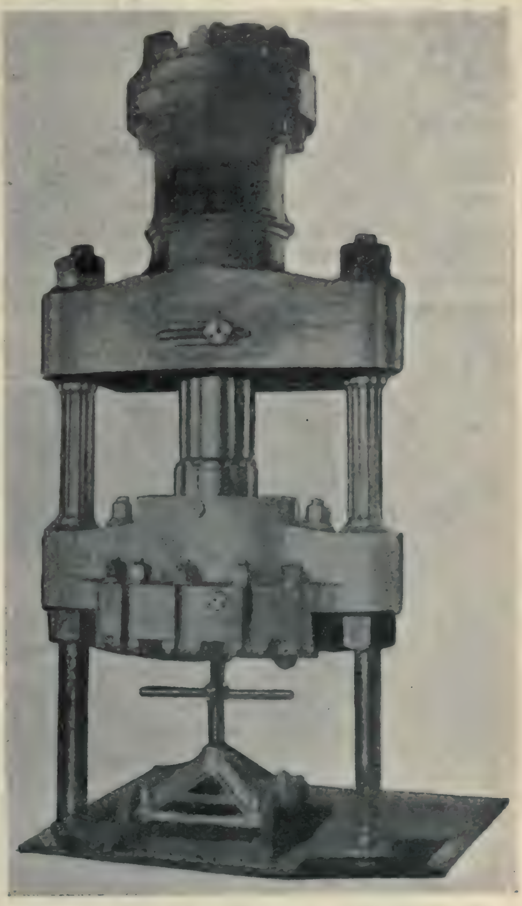


FIG. 131.—Mongin's filter press (strainer).

Drying.—The washed gutta percha is placed in the drying oven, a steam-jacketed cast-iron rectangular case *A B C D* (Fig. 132) closed in its upper part by a semi-cylindrical lid *A E D*, provided with a movable part *E F*, which can be kept in place by solid iron bars. Inside the case are two rolls with parallel axes, bearing helicoidal grooves in opposite directions, and turning contrary to each other. The gutta, seized between the two rolls, spreads into the empty grooves, and thus constantly presents fresh surfaces to the contact of the hot air in the case. The condensed water collected in the bottom, is evacuated through *O*, the expelled moisture through *F*.

Kneading or mastication.—Before trying to convert the gutta percha thus purified into industrially wrought articles, it is necessary to free it from all traces of water, and especially from interstitial air, and to convert it into a united homogeneous mass. The elimination of air is very important, because the presence of the least trace diminishes, if it does not completely sup-

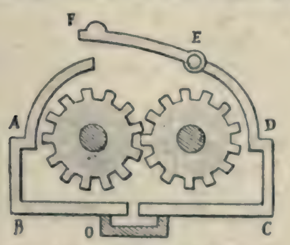


FIG. 132.—Section of a drying machine (after Wunschendorff).

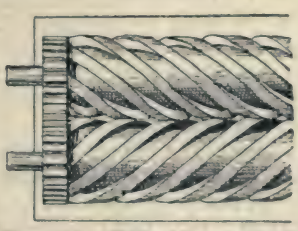


FIG. 133.—Helicoid grooves of the cylinders of the preceding drying machine.

press, the adherence of its different parts. Purified gutta percha, therefore, is not employed without having been passed through a masticator, a "devil," or a "wolf,"

if it be not desired to work a defective gutta percha, called in the language of the trade strawy gutta.

Masticator.—The purified gutta percha is softened in a double-bottomed cast-iron pan by steam, and then passed through the masticator (Fig. 134), consisting of a cylindrical case laid horizontally, in the axis of which turns a solid cast-iron roll, the surface of which is covered with longitudinal grooves in such a manner that in a cross-section it exhibits the appearance of a toothed pinion. The diameter of the roll is a little less than that of the cylindrical case which envelopes it. In turning, it draws with it the gutta percha which has been introduced between the two, compresses it between its grooves and the sides of the cover, brings the molecules together, and agglomerates and binds them to each other, whilst the imprisoned air is at the same time expelled. The lower half of the cylindrical case is often jacketed, so that a jet of steam may be run in as required. The grooved roll is driven round by means of the pulleys and cog-wheels shown in the drawing. At the commencement of the masticating process, a current

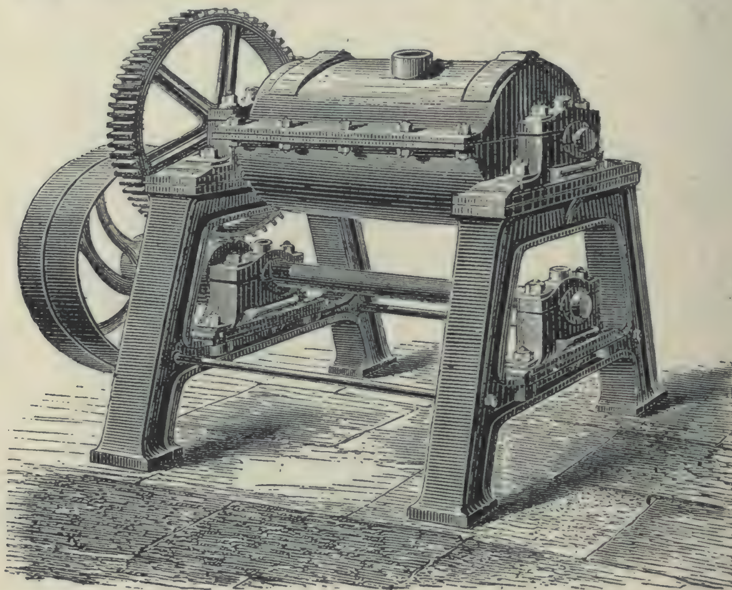


Fig. 134.—Leblanc's masticator.

of steam is passed through the double bottom, the steam is then regulated so as to maintain a suitable temperature, taking care to take into account the heat produced in the mass by friction. After having been masticated, gutta percha is ready to be utilised. It is generally passed through rolls, converted into sheets; it is afterwards stored in this form in cellars.

The kneading machine or masticator as described by Obach resembles the washer, but the roller has a smaller diameter and the flutings are more numerous and not so deep. The hinged lid is kept down by a bar and suitable catches. The gutta percha is kept hot during mastication, and the water escapes in the form of steam through the large openings at the top. The washers usually hold $\frac{3}{4}$ cwt., the masticators 1 cwt., and the strainers $\frac{1}{2}$ cwt. of gutta percha.

Obach determined the percentage of water and dirt in various kinds of gutta percha; some of it, about 3 per cent., is removed during the preparation for the washer, but the greater part is eliminated during the first washing operation. The straining hardly affects the percentage of dirt. Straining is in fact more of a precaution to avoid large particles of dirt of a fibrous nature being left in the

clean gutta percha. The second washing operation, that after the straining, is also efficacious as it eliminates about another ½ per cent. There still remains about 1·8 per cent. of impurities which are allowable for general purposes, but for special uses the percentage of impurities has to be lowered to a minimum.

Loss.—Like indiarubber the different species of gutta percha thus suffer an appreciable loss during the purification process, varying with the sources and the qualities. The loss during cleaning and drying, says Obach, is a heavy one, and is occasionally fully 50 per cent. The best sorts generally lose 15 to 20 per cent.; intermediate kinds, 20 to 25 per cent.; and inferior qualities, 25 to 30 per cent. and more. Taking these losses into account, the cost price of the purified gutta percha can be fixed. Thus a substance which is bought raw at 12 francs the kilogramme (say 4s. 4d. the lb.), and which during purification loses 20 per cent., for example, costs 15 francs the kilogramme (5s. 6d. per lb.), without taking into account the heavy expenses incidental to purification.

The percentage of gutta percha actually obtained in the works is invariably lower than that shown by analysis. In sampling both moisture and dirt escape, and large stones are not included. To counterbalance this, an allowance is made of 9 per cent. on the gutta percha found by analysis or say 6 per cent. on the raw material. The $\frac{G}{R}$ is better with cleaned gutta percha than with raw materials. The analysis extracts resin from raw material and from wood and bark. This does not occur on cleaning. Again, raw gutta percha is more porous and thus more pervious to solvent than the denser clean material, the resin is therefore more completely extracted from the former than the latter.

TABLE CXXII.—SHOWING GUTTA PERCHA AND WASTE AS FOUND BY ANALYSIS AND AS ACTUALLY OBTAINED ON WORKS BY MECHANICAL CLEANING (OBACH).

	I. Genuine.			II. Soundie.			III. White.			IV. Mixed and Reboiled.		
	Pahang.	Bulongan Red.	Banjer Red.	Bagan.	Kotaringin.	Serapong.	Bulongan.	Mixed.	Banjer.	Sarawak Mixed.	Padang Reboiled.	Banca Reboiled.
Average—												
Gutta percha G + R .	70·3	70·0	60·7	74·5	77·6	70·4	69·6	64·5	51·3	60·3	56·8	72·6
Waste D + W . .	29·7	30·0	39·3	25·5	22·4	29·6	30·4	35·5	48·7	39·7	43·2	27·4
Ratio $\frac{G}{R}$ . . .	4·3	2·8	2·0	1·5	1·5	1·3	1·2	1·2	1·1	1·4	0·9	0·9
Analytical results—												
Gutta percha G + R proper . . .	69·8	70·5	61·6	75·8	78·9	72·7	66·8	65·2	58·3	62·6	58·7	74·1
Waste D + W . .	30·2	29·5	38·4	24·2	21·1	27·3	33·2	34·8	41·7	37·4	41·3	25·9
Ratio $\frac{G}{R}$ . . .	4·2	2·5	2·1	1·4	1·4	1·2	1·1	1·1	1·1	1·4	1·0	0·8
Actual works' results—												
Gutta percha (cleaned)	65·7	64·7	55·3	68·0	74·2	64·3	56·4	64·1	53·5	55·5	55·3	70·8
Waste D + W . .	34·3	35·3	44·7	32·0	25·8	35·7	43·6	35·9	46·5	44·5	44·7	29·2
Ratio $\frac{G}{R}$ . . .	4·2	2·5	2·3	1·4	1·3	1·4	1·2	1·1	1·2	1·4	1·1	0·9
Ratio of G. P. by analysis and on cleaning . .	1·06	1·09	1·11	1·12	1·06	1·13	1·18	1·02	1·09	1·13	1·06	1·05
	1·09			1·10			1·10			1·08		
	1·092											

Chemical purification of gutta percha.—Hancock (Charles) in his British Patent (11, 208 O.L.) of 15th May, 1846, steeps raw gutta percha after being cut into small pieces in a caustic alkaline lye or in a solution of bleaching powder to neutralise acidity and remove any bad smell. If hot alkaline lye is used in the washer instead of water, the crude gutta is cleaned far better and is much paler in colour. Obach washed a particular raw gutta (belonging to a class which do not readily cede their impurities) twice with water, then rolled it out into a sheet and analysed it. It contained 12·7 per cent. of water and 1·7 per cent. of dirt. Another portion of the same raw gutta percha was washed with a 5 per cent. solution of caustic soda, then with water; on being rolled out into a sheet gave on analysis only 5·2 per cent. of water and 0·4 per cent of dirt. Alkaline lyes not only lower the percentage of dirt to less than a quarter the amount, but it also reduced the capacity for retaining mechanically enclosed water. But the washing of gutta percha with hot alkaline lyes or other chemicals must be done with care and judgment, and the subsequent washing with water must be done very thoroughly, otherwise the gutta percha may be damaged and perish within a short period.

The chemical hardening of gutta percha.—Obach hardens gutta percha by extracting the resin from it by petroleum ether extraction plant on a large scale. He uses gasolene of 0·65 to 0·67 gravity. He first chops the gutta percha then throws it through a screen on to a long drying platform heated underneath by steam pipes. It is shovelled along and continuously turned over until it reaches the end of the first platform, where it is thrown on to a second and lower platform and then similarly moved along to the other end. It is then fairly dry, but to completely dry it, it is thrown into a hopper of a long iron drum with narrow shelves, which take it round a certain distance, when the drum is rotated and at the same time moves it along, since the rotation axis is slightly inclined towards the other end. A gentle current of warm air passes through the drum in an opposite direction, carries away the moisture given off by the material and so accelerates drying. After leaving this drum the pieces enter a sifting drum and the coarser pieces move along inside until discharged at the other end, where they fall into an upright iron vessel fitted with a distributing arrangement. But the finer material drops on to an endless band and is carried to a bin. The coarse and fine matter are thus separated. A galvanised iron tank, fitted with a hinged lid and a movable plate in front, and capable of being carried about by an overhead travelling crane, is first charged with a layer of coarse pieces from the upright iron vessel, then with finer stuff from the bin, and finally with coarse pieces, the depth of each layer depending on the material. This facilitates percolation during extraction. The bottom of the tank is perforated and fitted with wire gauze, when charged it is deposited in one of a series of larger tanks connected up *en cascade* by piping. These tanks, after each having received one of the smaller ones filled with raw gutta percha, are worked in groups of three. Gasolene from a large store vessel overheated is admitted to No. 1 tank of each group and flows over into No. 2 and thence into No. 3, filling all three in succession. The circulation of the spirit is continued until it is found to be quite clean as it leaves No. 1. This tank is then disconnected from the other two and a tank with fresh raw material connected with the former No. 3. The former No. 2 now becomes No. 1, and so on. The solution from No. 3 is pretty thick, containing a large amount of resin. It is run into a tank, and from there in a continuous stream into a large still fitted with a steam coil at the bottom. The contents of the still are heated, the spirit distilled off and condensed in a suitable cooling arrangement, which delivers it into the main store tank in the cellar, whence it is pumped up again into the feed tank. The spirit from tank *A* is run off into the store tank, the gutta percha further washed with clean spirit, then allowed to drain whilst communication still exists with the store tank. The inner tank is now lifted out and brought in front of a large masticator. It is laid on its side, pushed into the masticator, and the contents discharged by withdrawing the side of the tànk which now forms the bottom, the

masticator having been previously filled with cold water. After removing the tank, the large swing door of the masticator is closed. Steam is turned on and the roller set in motion, so as to knead the gutta percha whilst the solvent is being distilled off. When the distillation ceases the remaining vapours are blown over into the condenser by steam, the masticator is then opened, the gutta percha taken out and washed in the usual way with water, or if necessary with an alkaline solution. The distillation of the resinous solution is carried on until the contents of the still have become very thick and the solvent in consequence distils over only tardily. The supply of fresh solution is then interrupted, the valve between still and condenser closed, but the heating continued until a certain pressure has been produced by the vapour, which is then utilised to force the contents of the still into another still situated at a safe distance outside the building, where the heavier parts of the solvent are distilled off by direct fire heat. The contents of the still are then discharged through a kind of treacle valve and run into barrels or other suitable receptacles for further use or sale. All the various tanks are connected by a system of steam pipes and air pipes, provision being made that flames cannot spread from one to the other in case of fire. The main pipe of this system is finally carried to the vessel containing the coarse pieces of dried gutta percha (two of these vessels are used alternately). The air in passing through the gutta percha

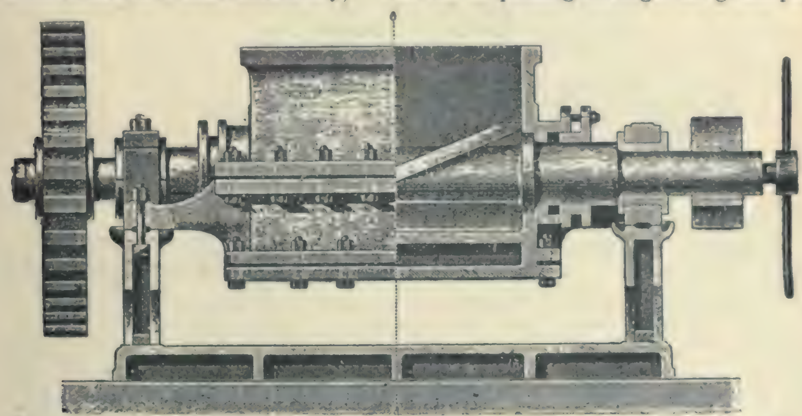


FIG. 135.—Mixer with three cylinders at work in Messrs. Siemens' factory, London.

before being discharged into the open is thus deprived of all vapours, which is very desirable for safety as well as economy. Obach describes an experiment to demonstrate the efficacy of the hardening process. Two pieces of raw gutta percha are cut from the same block; one piece is kept in its original condition, but the other is heated with petroleum spirit to extract the resin as completely as possible, and then freed from the resin *in vacuo* at a slightly elevated temperature. A large vessel containing water is heated on a sand bath until the water acquires a temperature of 50 per cent. A smaller glass beaker also containing water is immersed in the outer vessel, and its contents therefore have practically the same temperature or if it should be different a slightly lower one. The original matter is now thrown into the inner vessel and the hardened one into the outer, and they are left there for a short time until they have acquired the temperature of the water. The piece of treated gutta percha is then squeezed between the fingers, but it resists the pressure as it is still quite hard. The same test is applied to the original material inside the beaker, and it will be found to be quite soft and plastic.

The mixing of gutta percha.—Purified gutta percha is often mixed with other substances, either to lower its cost or to make it harder and more resistant. The substances most often used are chalk, sulphate of lime, sulphate of baryta (barytes), asphaltum, oxides of zinc and of lead, etc. etc. By varying the proportions and the nature of the substances incorporated with gutta percha, products of variable

consistency are obtained, which are for the most part firmer, but very inferior to the primitive product. By adding a certain amount of caoutchouc, its suppleness

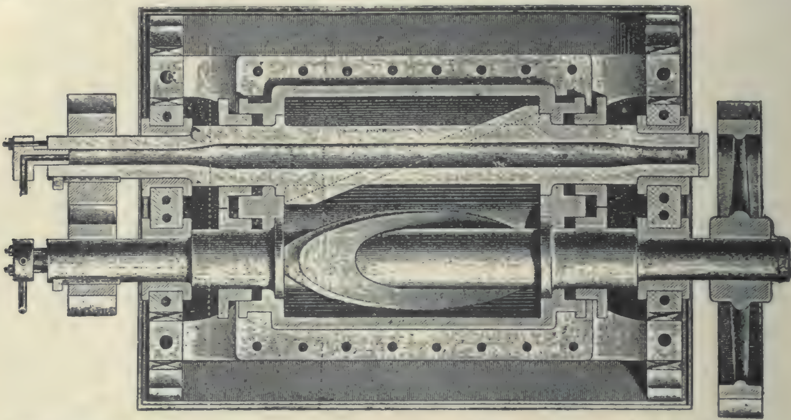


Fig. 136.—Mixer with three cylinders at work in Messrs. Siemens' factory, London.

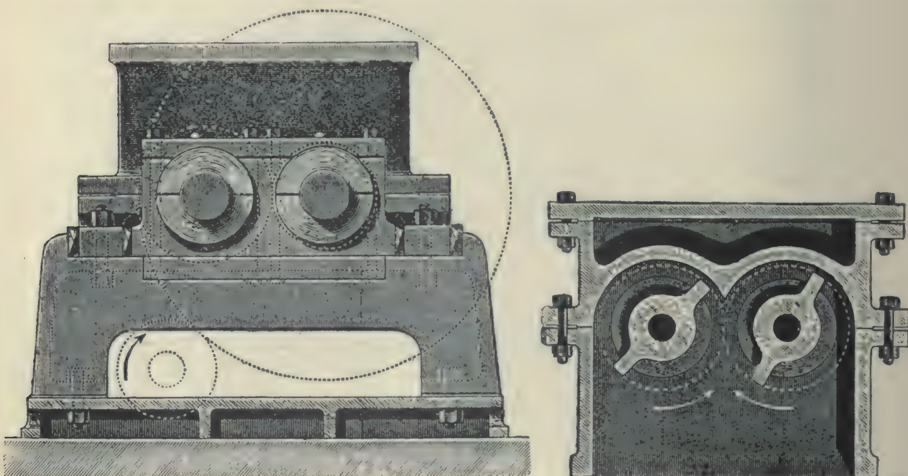


Fig. 137.—Mixer with three cylinders at work in Messrs. Siemens' factory, London.

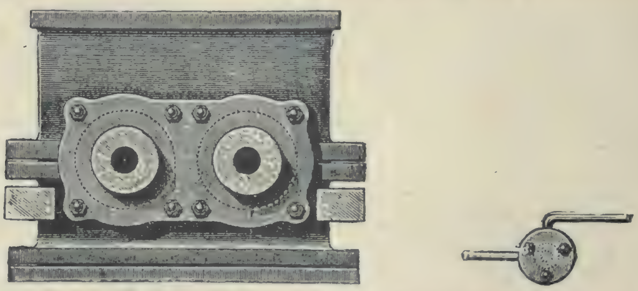


Fig. 138.—Mixer with three cylinders at work in Messrs. Siemens' factory, London.

and elasticity are, on the contrary, increased. An infinite number of substances may be incorporated with gutta percha, and from that fact alone it will be easily perceived that an infinite number of mixtures, endowed with different properties,

may be obtained. The incorporation of accessory substances with gutta percha may be done during mastication. The purified gutta percha is first masticated and wrought in the machine until it is well softened. The substances in fine powder are then gradually introduced into the masticator, which is put in motion, and made to act until the mass becomes homogeneous. This process of mixing, or mastication, has the disadvantage of not always completely eliminating the

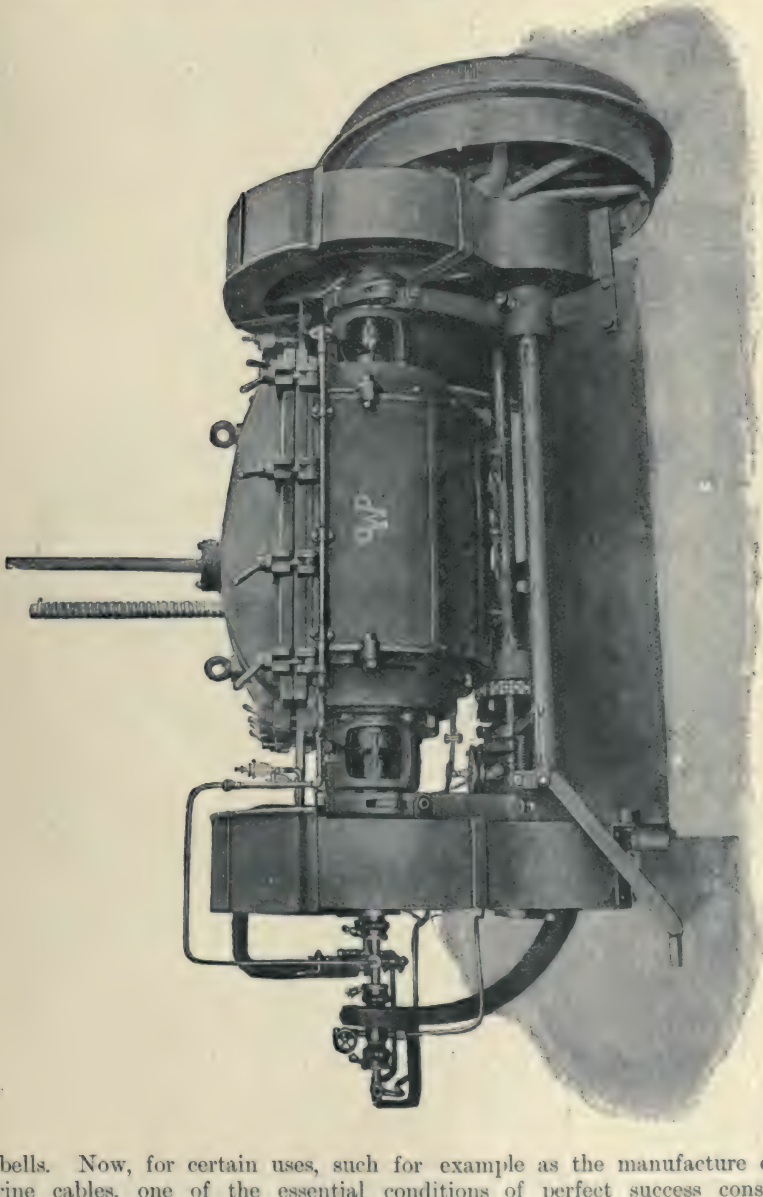


Fig. 139.—Masticator for Gutta Percha.

air-bells. Now, for certain uses, such for example as the manufacture of submarine cables, one of the essential conditions of perfect success consists in obtaining a paste free from all traces of these air-bells. The masticator shown in Fig. 134 has been designed with this end in view. Like the ordinary masticator, this machine consists of a steam-jacketed cylindrical vessel, but instead of having only one grooved cylinder it is provided with three of these organs. The

masticating cylinders are much less in diameter than the interior periphery of the vessel, and each of them is furnished along its length with a cutting blade, fixed somewhat crosswise, and slightly twisted. This blade does not touch the sides of the vessel, from which it is always 5 centimetres (say 2 inches) apart. A driving shaft gears on to the cogwheel fixed at one extremity of the cylinder, and imparts to it a speed of twenty-five revolutions a minute. Each of these masticating cylinders is arranged in such a way that its driving wheel is in an opposite direction to its neighbour. The cylinders therefore revolve in opposite directions, in direction of arrows. Their relative speed against one another is about 4 to 5. It is in this arrangement that the economy of the machine consists, for, whilst the cylinders work with different speeds, the cutting edges meet each other at each revolution in different places, and cut the gutta percha each time at a fresh spot. As soon as cut, the substance is pushed through the empty space which is produced between the blade and the cylinder as far as the centre, where it is again cut, finally going to the right or to the left, where the wings of the cutting blades raise it up on to the cylinders, so as to cause it to again fall to the centre. In this way the gutta percha never remains agglomerated into a single mass, and is always being cut, now on the one side, and again on the other; it is masticated throughout, eliminating any small air-bells which it may contain. This process, it is said, yields a perfect gutta percha, whilst it only takes half as long as the ordinary process. The cylinders are hollow, so that the substance does not

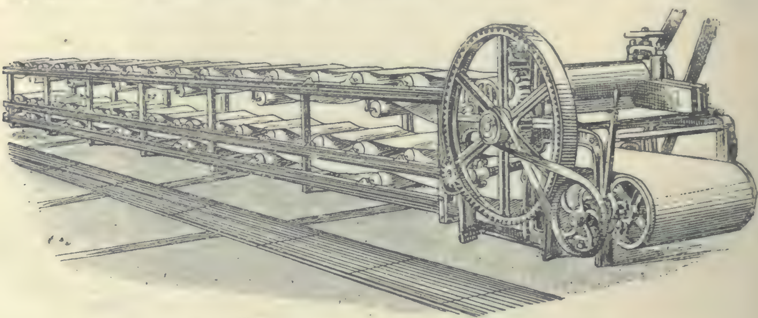


Fig. 140.—English rolling mill (after Wunschendorff).

become adherent during the process, and a current of cold water is passed through as required. As it comes from the masticators, gutta percha is ready for industrial use, whether it be used directly, or after it has been converted into sheets, by being rolled, and in that form subjected to ulterior operations.

Lamination or rolling.—The soft gutta percha from the kneading machines is laid on a table in front of a pair of parallel rollers. It is then fed between the two very smooth rolls, turning in opposite directions; the substance passes through the free space between the two rolls, and is caught by a long endless web, of the same width as the rolls on which it travels, some distance to and fro, until it is sufficiently cool and hard to be sent into the shorter lengths for storing. The thickness of the layer of gutta percha is about 2 centimetres (say $\frac{3}{4}$ of an inch); it is cut into pieces of 30 to 40 centimetres (say 11·8 to 15·7 inches) wide, so as to form sheets which can be stored in the cellar, protected from the air, light, and dust, until required for use (which gives $\frac{1}{8}$ to $\frac{1}{4}$ inch thick and 6 feet in length as suitable dimensions).

French methods.—The English method of purification has now been given with full details. French manufacturers, whilst seeking a high degree of perfection in their products, aim at more simple methods. At Benzons, gutta percha, as it comes from the mincing machine and simply re-heated, is brought direct to the filter press, and from there into the washing machine called the *Truman* (Fig. 143), of quite a special arrangement (British Patent, 637; 1861).

This washing machine consists of three rolls, of about 10 centimetres (say 4 inches) in diameter, arranged at intervals of 120° round a central axis, to which they are fixed by cast-iron cross-pieces, and driven by the general horizontal shaft of the factory. The axis turns with the three rolls, inside a hollow cast-iron cylinder, furnished with a lid, which is pierced by two large holes *R*, which may be firmly fixed on the cylinders. The whole is enclosed in a large wrought-iron case *M N O P*, filled with water. The gutta percha, pressed by the rolls against the cylinders, constantly presents fresh surfaces to the contact of the water, and abandons a portion of its impurities, which fall to the bottom, whence they are withdrawn when the operation is terminated. The gutta percha is treated for two hours at least in the machine, and then wrought in the drying masticator, which is in every way analogous with the English drying machine. The grooves, however, are interrupted on the cylinders at intervals of 10 centimetres (4 inches), so as to force the material in contact with the air to renew itself more frequently. As it issues from the masticator, the gutta goes directly to the rolling mills. In Menier's factory at Grenelle, the rolls of the laminator are very close to each other, so as to produce very thin sheets, which are exposed to the air for seven or eight days, so as to dry completely. These sheets are then re-masticated, and

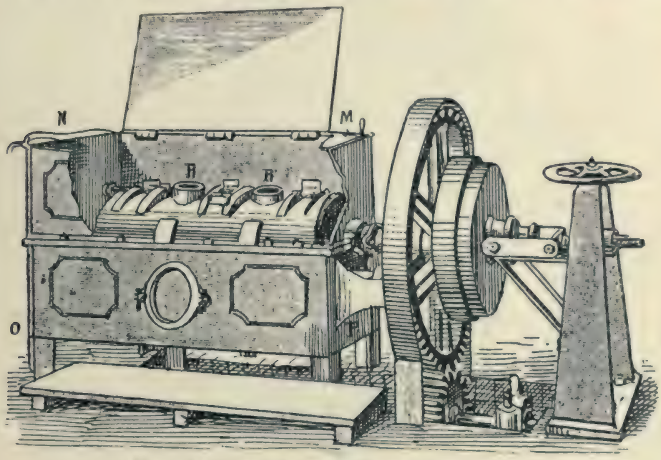


Fig. 141.—*Truman* (after Wunschendorff).

passed through a second rolling mill, which yields cakes for warehousing. This gutta contains less water, but it is more liable to oxidation.

Bleaching of dental gutta percha.—The dental profession utilise gutta percha, not only as a mastic to fill the gaps due to caries, but also to make mouth-plates for artificial teeth. The substance ought to be perfectly white for this special use, and it will not be out of place to know the different bleaching processes adopted. In a close vessel 500 grammes of gutta percha are digested with 10 kilogrammes of chloroform (say ½ lb. of gutta percha and 10 lb. of chloroform). When the substance is entirely dissolved, 200 to 300 grammes of water (say 3 to 5 oz. for the above English proportions) are added and energetically stirred, and the mixture abandoned to itself for a fortnight. All impurities collect on the surface of the water, floating on the chloroform. The clear limpid solution is drawn off into a porcelain dish, fitting into a copper still made for the purpose. After covering the liquid with a small layer of pure water, water is run into the still up to about the third of the exterior height of the porcelain dish, and the chloroform is distilled off. The white, slightly yellowish, rather honeycombed residue consists of purified gutta. Sometimes, before distilling, the solution is treated by animal charcoal, which makes it still more white. This honeycombed mass is masticated so far that it may be made into very homogeneous sticks, which, preserved for some time in ether

or alcohol, become more and more decolorised, and end by taking a white, diaphanous appearance, like the best ivory. All trace of chloroform must be eliminated, otherwise the gutta percha will become brittle.

Another process.—One part of fine gutta percha is dissolved in 20 parts by weight of hot benzol, and $\frac{1}{10}$ part of plaster of Paris. After digesting for two days, the perfectly limpid, liquid portion is decanted, then poured into twice its volume of 95 per cent. alcohol. The gutta percha is precipitated as a white, brilliant, rather soft mass, which is collected, masticated, and preserved in blocks in a place free from all contact with dust and light. If it be desired to imitate the natural rose colour of the gums, one part of cochineal carmine for 800 to 900 parts of gutta percha is crushed in a little water, thickened with gum arabic, and the product mixed with the chloroform solution before distilling. The distillation residue takes a uniform rose tint when masticated.

Reclamation of gutta percha waste.—The processes for reclaiming gutta percha waste, whether from old objects, worn out through long use, or whether simple factory waste, are very simple. Certain precautions must, however, be taken if a really practical result be desired. All old articles are not equally worth reclaiming, and it would be better to neglect some of them altogether. Thus

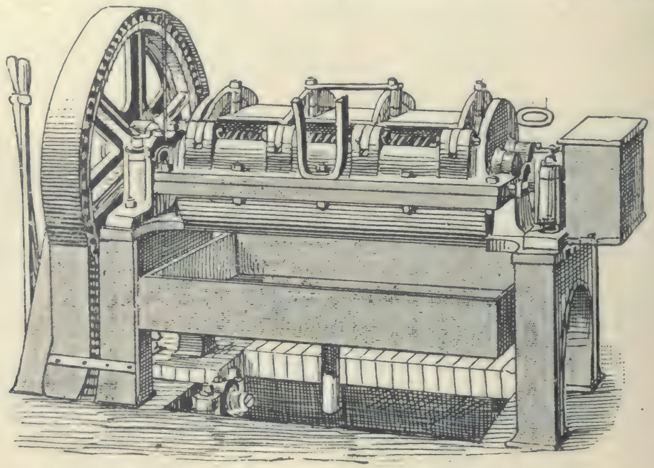


FIG. 142.—Masticating drying machine (after Wunschendorff).

bottles which have been used to hold acids for some time, and chiefly hydrofluoric, are worthless. They cannot be again "cured," according to the typical expression of Guillot, one of our most skilful practical men in this class of industry, who, with his usual courtesy, has been good enough to initiate the authors into the little secrets of his manufacture. It is the same with certain photographic dishes, which, after a certain time, resinify completely. It is then impossible to soften them so as to utilise them again. One of the best kinds of gutta percha waste is that from spindles for weaving, whether it comes from spindles discarded by too long use, or whether it consists of cuttings originating in the manufacture of these appliances. In regard to waste wires of electrical conductors, a previous sorting out is necessary, some being really of superior quality, others being prepared with very inferior guttas, often mixed with vulcanised rubber. The latter sorts are reclaimed with exceeding great difficulty, and the industrial results obtained are of little commercial value. The best thing to do with waste of this nature is to heat it in water to which a little caustic soda has been added, then to swell it in benzine or spirits of turpentine. In this condition it is passed to the filter press. The solvent employed is evaporated at a rather low temperature. The product obtained is used as an adjunct in a fresh manufacture of the same

kind. However, the reclaimed waste is far from being equal in value to that about to be described. The following is the process generally adopted to work up gutta percha waste of a good quality :—The manufacturer having a lot of known value and composition, softens it in ordinary water at about the boiling-point. If the gutta percha be not too resinified, this softening is soon accomplished (in about one hour). In the contrary case, the time required is longer, and proportional to the alteration. The sufficiently plastic substance is taken from the pan by a shovel, and thrown on the floor, lined with a piece of tinned sheet-iron, in

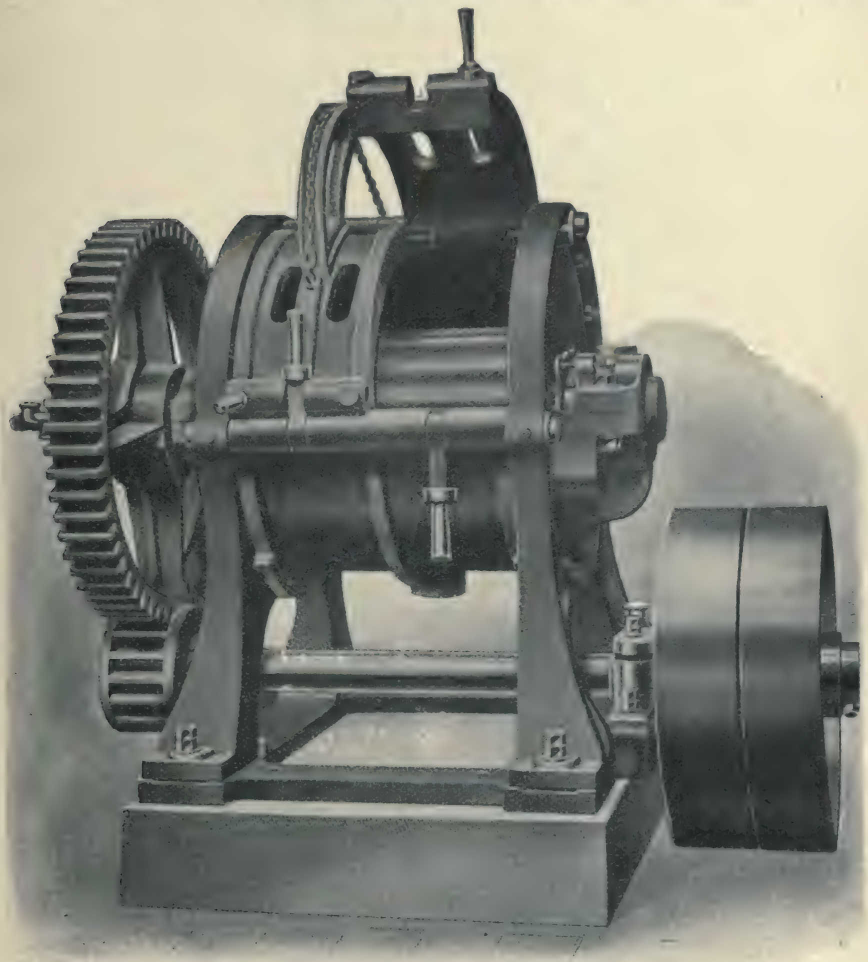


FIG. 143.—Masticator, Bertram, Leith.

front of a set of double rolls, capable of being set at various distances. After having sufficiently moistened the rolls, to prevent adherence, the very hot paste is passed several times between the rolls, passing them each time in a direction contrary to that of the preceding passage, so as to obtain the greatest possible homogeneity, and leaving a sufficient space between the rolls for the cake to pass through with such rapidity that it has not time to get cool. As it comes from the cylinder, the gutta percha is each time rolled upon itself so as to form a rather bulky block, which the workman receives on his table, or which he seizes by hand,

to again pass it through. Finally, the rolls are squeezed near to each other, and the cakes obtained are passed through a second time, but this time without refolding the sheet on itself, but allowing it to spread out in a flat "pig" on the sheet of tinned iron below the rolls. Unless the waste so reclaimed be intended to be used forthwith, the sheets are stored in a place protected from air, light, and moisture, to be sold later on, or made into articles of manufacture. In the latter case, whether the waste be used alone, or whether it be mixed with fresh gutta percha, the sheets are again softened in a bath of hot water, and passed between the laminating rolls, but this time, after being spread between two sheets of tinned iron, which pass between the rolls at the same time as the gutta percha, to be rolled. The sheets of reclaimed gutta percha are thus uniformly extended between the sheets of tinned iron, and the desired thickness is obtained, regulating appropriately the distance between the rolls. Gutta percha waste (generally black) loses its colour more and more after a prolonged passage through hot water, and reclaimed gutta percha thus acquires a chocolate brown colour, which becomes less and less intense. If, finally, the waste be much oxidised, it is better to use, instead of ordinary water, water rendered alkaline by a little caustic soda. It is necessary to conduct this operation with great caution, so as not to deteriorate the substance.

The so-called vulcanisation of gutta percha.—In a number of treatises in the special literature of the subject, processes for the vulcanisation of gutta percha are treated with the greatest of seriousness. That it was attempted, in the first moments of infatuation, to apply vulcanisation to gutta percha may be readily conceived, but it is incomprehensible how chemists of the standing of Heinzerling could, thirty years after the first attempts, still describe the early formulæ, although they knew perfectly well that the action of sulphur and halogens, far from having a satisfactory action on gutta percha, are, on the contrary, injurious to it, and can only compromise the value of a substance the selling price of which is already sufficiently high, without spoiling it foolishly and unreasonably. Heinzerling, after having described at length what has been attempted in this connection, concludes with this melancholy phrase, which well depicts the small confidence which he accords to these processes: "*We have given these processes of vulcanisation to be complete, but we cannot believe that at the present time any one still makes articles of vulcanised gutta percha.*" It will be well to pass the unfortunate experiments silently. Homogeneity and plasticity being the principal qualities to exact from gutta percha, too great care cannot be taken to prevent the introduction into it of a body which would diminish this homogeneity, and which would deprive it to a great extent of its plasticity.[1]

[1] Fayol, *Le Caoutchouc*, 1909, p. 122, treats the vulcanisation of gutta percha quite seriously. He says "it is washed, scoured, reduced to sheets, masticated and laminated, then it is vulcanised with 2 to 3 per cent. of sulphur; it is also vulcanised with orpiment. This operation renders it less fusible and gives it more resistance towards acids.

CHAPTER VII

METHODS OF ANALYSING GUTTA PERCHA.

Crude gutta percha.—Is there any need of insisting upon the necessity for a method of analysing commercial gutta percha? As in the case of rubber, the principal physical properties characteristic of each of the principal commercial varieties are given in a synthetic Table; but such data are not sufficient when it is a question of important purchases or delicate work, such as covering the insulators of electric wires, and especially of those of submarine telegraph cables. If it be useful for manufacturers to know (*a*) the precise quantity of water exceeding the normal, (*b*) the total amount of the inert substances, accidentally or intentionally interposed, (*c*) the quantity of oxidised or resinified gutta, (*d*) the total amount of ash which would be produced on incineration of each of the varieties on the market, it is also necessary to know, (*e*) at least approximately, the quantity and nature of the foreign resins incorporated intentionally into gutta percha (1) to lower the price, or (2) rather to increase the profit of the collector, the native merchant, the middleman required between the working collector and the merchant of Macassar or Singapore. If a determination of (*f*) its tensile strength is likewise useful, there is still a more indispensable test when it is a question of making wires for submarine cables, namely, (*g*) the specific electrical resistance of any given sample of gutta percha.

1. *Sampling and moisture determination.*—The methods pursued are those described for the analysis of crude rubber. Montpelier, chemist of the French Telegraph Administration, prescribes that, in the estimation of water, the gutta percha to be tested should be dried at 100° to 110° C. (212° to 230° F.) in a current of carbonic acid. The oxidation of the gutta percha is thus prevented, and there is no reason to fear an increase in weight which may exceed that of the water evaporated. Water can be determined with sufficient accuracy for most practical purposes by gently heating a weighed quantity first in the open air and then *in vacuo* over an absorbent substance until no further loss occurs, but sometimes it has to be ascertained by direct weighing. Obach, in the analysis of cleaned gutta percha, heats the gutta percha in a current of rarefied air or hydrogen, and absorbs the moisture in sulphuric acid in a weighed U-tube. The gutta percha, preferably as a thin sheet, is cut into small pieces and divided into two portions; in one the water is determined by heating in a current of rarefied air or hydrogen, and absorbing the moisture by sulphuric acid in a weighed U-tube; in the other portion, resin, gutta, and dirt are determined.

2. *Ash.*—The ash in pure gutta percha should not exceed 0·570 per cent.

3. *Valuation from analytical results.*—Finally, according to the numerous experiments of Lagarde, the gutta perchas used as dielectrics having a maximum of 0·50 per cent. of mineral matter and 5 per cent. of water are held to be good when they contain at least 58 to 60 per cent. of pure gutta, and very good with 65 per cent.

4. *Adventitious vegetable and mineral matter.*—These are determined in the lumps as in the case of rubber, but, instead of spirits of turpentine or benzol as solvent, it is preferable to use carbon disulphide and toluene, which dissolve gutta percha better than all other vehicles.

5. *Resin.*—This is one of the most important points in the analysis of gutta percha, namely, the determination of the oxidised resinous principles which are naturally present in the sample, and the amount and nature of the resins accidentally added for some purpose in one way or another. The point is difficult and complex, and, without completely solving the problem, the following are some useful hints:—The method of preparing pure gutta and separating it from fluavile and albane furnishes the most natural analytical method for determining the amount of the oxidised products which always accompany gutta percha. This amount varies with the nature of the plant, its age, the soil, and, finally, with the more or less recent date of the preparation of the gum resin. But this process, based on the prolonged boiling and repeated washing of the finely divided raw product in 95 per cent. alcohol, has the drawback of extracting a little gutta percha in the alcoholic solutions, and cannot be regarded as rigorously exact. The boiling alcoholic solution contains, besides albane and fluavile, the foreign resins used to sophisticate the commercial product, as well as the oxidised resins due to contact with air and light. The following is the method adopted by the authors in the analysis of a commercial gutta percha whose abnormal structure, colour, and smell pointed to an evidently adulterated gutta percha, and which had certainly become oxidised after its preparation. By the previously described process there was found in the sample analysed—

Abnormal water	4·5 per cent.
Vegetable débris and mineral matter .	3·0 ,,
Pure gutta	68·0 ,,

The boiling alcoholic washings were allowed to stand for five days at a temperature of 10° C. (50° F.), then repeatedly filtered until the filtrate was perfectly limpid. The granular precipitate, which consisted of albane and fluavile, dried during eight days *in vacuo*, yielded 12 per cent., and consisted, according to all known reactions, of the two proximate principles, fluavile and albane. The evaporation of the mother liquor—consisting of alcohol, and of resin, whether of spontaneous oxidation or added, dried *in vacuo*, and protected from air and light—yielded a residue similar to an amber-yellow varnish, almost transparent, rather soft and tacky, weighing 12 per cent. This residue, redissolved in weak alcohol (50 per cent.), and treated with caustic soda, after one and a half hour's boiling, only left an insoluble residue of 8 per cent., whilst the soda solution had evidently absorbed about 4 per cent. (resin soap). The 4 per cent. of residue dissolved by the caustic soda may be regarded as the product of the spontaneous alteration of the gutta percha, whilst the 8 per cent. appears to come from a resinous substance added purposely. This substance—very difficult to dry, rather like glue, of a straw-yellow colour—burned with a very smoky flame, and gave off a characteristic smell rather similar to that of Borneo caoutchouc.

Obach's methods for analysing gutta percha—1. *Determining resin.*—The resin is extracted by means of cold ether, the solution distilled, and the residue carefully heated and weighed. (The gutta and dirt remaining after extraction of the resin are dried *in vacuo* and weighed so as to check the other result.) 2. *The determination of gutta.*—The gutta in its turn is then dissolved in carbon disulphide or chloroform, the solution filtered, and the solvent distilled off. The gutta so obtained is dried *in vacuo*, and weighed and then softened, and pressed into the form of a plate, which is tested for elasticity and strength. 3. *Dirt.*—To facilitate the separation of dirt from the gutta solution, the latter is centrifuged, or it is mixed with alcohol or water, according as the solution has been made in carbon disulphide or chloroform respectively. In standing the two hot liquids separate again, and the lighter one rising to the top carries the dirt with it, the clear solution can then be drawn off at the bottom. In this way results can be obtained which are sufficiently accurate for most practical purposes, although, scientifically speaking, they are not correct, as the resin is not completely separate from the gutta, and the latter still contains a certain amount of colouring matter. However, these disadvantages are

more balanced by the great convenience of this method for daily use in the laboratory in comparison with the other method of precipitating the pure gutta with alcohol.

Determining the percentage of resin in gutta percha by the density of the extracted solution.—Where only the approximate percentage of resin is required, Obach elaborated a process based on the increase of the specific gravity of a solvent ether, for instance, through the presence of resin. The apparatus consists of two glass tubes closed at their lower ends and fitted with rubber stopper through which pass the two ends of a narrow glass tube bent in the form of a ∩. A weighed quantity of gutta percha, cut into very small pieces, is put into one of the larger tubes, and a measured quantity of ether into the other. The ether is forced over into the first tube, and left for a certain time in contact with the gutta percha. It is then driven back, and its specific gravity measured with a special hydrometer which is provided with a thermometer. The apparatus stands in a wooden box, with glass windows back and front, so as to ensure uniformity of temperature, and special precautions have to be taken to guard against loss by evaporation, etc. The percentage of resin can be read off directly from the increase of gravity by special tables. With a less volatile solvent the viscosity might also afford useful indications.

Gutta perchas in which the percentage of resin reaches that of gutta, or even surpasses it, are of a decidedly inferior description. However, if the relative proportion of gutta and resin forms an important criterion for estimating the commercial value of a gutta percha, yet this in itself is not sufficient. Even putting aside for the moment the variable composition of the resinous components, there are, says Obach, guttas and guttas, and although the ultimate analysis of two different specimens may give exactly the same result, the physical and mechanical properties, and most important of all, the durability may widely differ, owing to a difference in their molecular constitution. It is therefore absolutely indispensable, in addition to the quantitative determination of the components, to scrutinize the gutta itself, which, it need hardly be said, requires much judgment and experience.

Table CXXIII.—Insulation in Megohms and Induction in Microfarads per Cubic Knot of Various Brands of Gutta Percha with Low and High Percentages of Water (Obach).

	I. Genuine.				II. Soondie.			
	Pahang.		Banjer Red.		Bagan.		Kolaringin.	
Water per cent.	1·5	6·5	1·4	5·2	1·7	7·3	0·8	7·2
Insulation	6,173	5,480	6,427	5,625	7,950	4,350	7,730	6,080
Induction	·5480	·0675	·560	·0592	·0521	·0682	·6080	·0662

	III. White.				IV. Mixed and Reboiled.			
	Banjer.		Bolungan.		Sarawak Mixed.		Banca Reboiled.	
Water per cent.	0·6	7·1	0·9	11·2	1·1	7·0	1·0	10·0
Insulation	10,410	6,454	57,910	39,030	24,250	24,250	82,320	68,020
Induction	·0555	·0898	·0575	·0890	·0664	·0718	·0648	·0753

Mechanical testing of gutta-percha.—As to resistance tests to a determined force, they should be conducted according to the method given for vulcanised rubber.

The difference in the nature of the two substances must, however, be taken into account. Rubber may be pulled in any direction, whilst gutta percha offers no resistance in a cross direction, and can only be pulled longitudinally.

Calculation of specific electrical resistances.—Before describing the most simple methods for ascertaining the specific resistance of different varieties of gutta percha, it will be well to recall some indispensable definitions for the perfect understanding of what follows. The resistance of a conductor is proportional to a factor, depending on the nature of the body forming the conductor and inversely proportional to its section; the factor f has been called the *specific resistance* of the body. If R be the resistance of a conductor, L its length, and S its section, these quantities are associated by the relation—

$$R = \rho \frac{L}{S}$$

The resistance of a conductor being proportional to a factor depending on the nature of the body, the factor called specific resistance is measured in ohms-centimetres and in microhms-centimetres for weak resistances, and megohms-centimetres for great resistances.

Insulators.—Bodies exhibiting great specific resistance are called insulators. In general their resistance varies with the conditions in which they are placed. It varies with the temperature, with the weather during which the substance is submitted to the electric current, with the pressure to which it is submitted. If caoutchouc at 0° C. (32° F.) has a specific resistance of $32{,}000 \times 10^6$, if caoutchouc at 24° C. (75·2° F.) has a specific resistance of $75{,}000 \times 10^6$, megohms-centimetres, the different varieties of gutta percha have a specific resistance varying from 25 to 500×10^6 megohms-centimetres.

Jenkin's method by the electrometer.—The insulation of a cable may also be ascertained by measuring, by means of the electrometer, the potential V of the battery with which the cable is charged, and that of v of the charge which remains in it after t'' seconds, and embodying these values in Siemens' formula—

$$R = \frac{0{\cdot}4353\ t}{C \log \frac{V}{v}}$$

But with these very high resistances the differences between V and v are very slight; and even under these conditions the values of V and v are limited by the condition of being contained within the scale of the instrument, which, as is well known, only contains 720 divisions. Fleeming Jenkin devised a method by virtually prolonging the scale so as to count the deviations from the starting-point of a very distant imaginary zero. By suitably choosing the zero in each particular case, deviations may always be obtained extending over the whole of the length of the actual scale. Suppose that one of the poles of a battery of 100 elements be run to earth, and the other connected with one of the pairs of quadrants, the second pair being itself in communication with the distant end of the insulated cable. If the cable be charged for a few moments to the same potential as the battery, the needle of the electrometer will first remain at zero; but in proportion as the charge is dissipated, the deviation increases. If the electrometer deviates 100 divisions, for example, for a difference of potential equal to the electromotive force of one element of the battery, a deviation of 100 divisions of the scale will be obtained each time that the potential of the cable lowers one hundredth of its value. The deviation will be 200, 300, 400 divisions when this potential diminishes 2, 3, 4 per cent.; in fact, if the potential becomes nil, the deviation, supposing that the construction of the instrument allows it, will attain a rather prolonged point of the scale that may be called the fictitious zero. In the above example the fictitious zero would be at the division 10·000.

In actual practice the pole of the battery (Fig. 146), which is connected with a pair of quadrants, instead of being insulated is run to earth through a resistance

coil R with an indicator m large enough for the battery not to be appreciably reduced by the closing of the circuit during the experiment. A double commutator key M_1 enables the current to be established, interrupted, or reversed. The indicator of the instrument is connected with a second double commutator key M_2, which again communicates—(1) by means of a circuit breaker I with two pairs of quadrants of the electrometer E; (2) with a commutator B of several directions to which the earth-plate T is attached, and the different cables L L to be tested, and which can be done simultaneously.

Method of operation.—The electrometer is charged by means of the recharger, and the luminous image is brought to the real zero of the scale. The indicator M is made to glide so that the ratio of the resistance ac comprised between the zero and the indicator, to the resistance $ab = 100$, is a very simple fraction; ac as a rule is chosen as $= 10$, which gives $\frac{1}{10}$ for the ratio of the two resistances ac, ab, and consequently for the fraction of the battery which serves to determine the fictitious zero. The plug of the circuit breaker I is removed; the commutator B is placed on the earth stud, then the springs of the key M are successively lowered and one of those of the key M_2. One of the pairs of quadrants is thus put in communication with the indicator m, the other directly with the earth; the product by 10 of the division at which the luminous image stops on the scale represents the division Z corresponding with the fictitious zero. The same measurement is retaken by reversing the poles of the battery; then the keys M_1 and M_2 are fixed in their normal position; the plug is put into the circuit breaker I, and the indicator is passed along to the 100 division of the coil R. One of the springs of M_1 and M_2 is again lowered, and at the time fixed for the commencement of the charge the

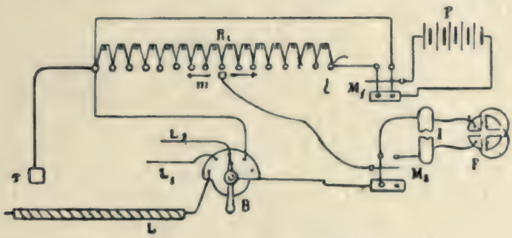


FIG. 144.—Electrometer.

handle of the commutator B is turned so as to place its axis, and consequently the complete battery P, in communication with the cable L to be tested: a charge of fifteen seconds generally suffices for 100 miles of cable. At the end of this time the plug of the circuit breaker I is withdrawn; in proportion as the potential of the cable decreases, the luminous index deviates further on the scale from the zero of the graduation. If we wish, for instance, to have the insulation at the end of the second minute, the deviations cl_1, cl_2 are taken corresponding to the time 1′ 45″ and 2′ 15″ from the commencement of the first contact of the battery with the cable and brought into the following formula—

$$R = \frac{0{\cdot}4343 \times 30}{C\,[\log\,(z - d_1) - \log\,z\,(z - d^2)]}.$$

Readings are taken at 4′ 45″ and 5′ 15″, and the deviations brought into the above formula if it be desired to get the insulation at the end of the fifth minute. When by exceptional lowering of the potential the luminous index would emerge beyond the limits of the real scale, it is made to re-enter by causing the indicator m to pass to the zero of the coil; there are then added to each of the readings on the scale the number of the divisions corresponding to the permanent displacement of the indicator. The measures so taken are very exact, not being affected by variations in the current of the testing battery, and are remarkably delicate, which may be increased indefinitely by increasing the sensibility of the instrument, the strength

of the battery, and the interval of time which separates the two readings. Moreover, with a single instrument in a manufactory a number of cables may be tested simultaneously.

Specific resistance of the dielectric.—These results obtained, let L be the length of a cable the insulating resistance of which is R, and ρ the specific resistance of the dielectric used; *i.e.* of a cube having the unity of length as its sides. Let us make in the cable a section perpendicular to the axis, and let us consider the layer of dielectric of the thickness dx situated at the distance x from the axis. The resistance will be—

$$d\,\mathrm{R} = \rho \frac{dx}{2\pi x l}.$$

If, therefore, d and D represent the interior and exterior diameters of the insulating envelope—

$$\mathrm{R} = \int_{\frac{d}{2}}^{\frac{\mathrm{D}}{2}} \frac{dx}{2\pi x l} = \frac{\rho}{2\pi l} \log \frac{\mathrm{D}}{d}.$$

Hence—

$$\rho = 2{\cdot}728 = \frac{2 \times \mathrm{R}}{\log \frac{\mathrm{D}}{d}}$$

log representing the common logarithms.

The resistance at the temperature of 24° C. of a cube of a metre of side is on an average for gutta percha

$$3{\cdot}55 \times 10^6 \text{ megohms.}$$

—(Jenkin's *Cantor Lectures.*)

Testing manufactured gutta percha.—It is sometimes important for the electrician, or the manufacturer of telephonic apparatus, to ascertain the greater or less degree of purity of the gutta percha which he is using. A comparative analysis can alone give him useful data. He ought to compare—by the estimation of the ash and by its approximate analysis—the suspected sample with a standard sample of known purity. If incineration is not sufficient, solution in carbon disulpide or toluene of the gutta percha to be analysed will give the amount and the nature of the mineral matter fraudulently added. As regards resins, bitumens, etc., they are easily estimated by treating the sample with boiling alcohol.[1] On cooling, the natural gutta resins are completely deposited by operating as described. The quantity, colour, smell, tint of the evaporation residue from the mother liquors, give sufficient data as to the proportion and nature of the adulteration.

[1] But even boiling alcohol has only a partial solvent action on bitumens, has little or no action on such pitches as rosin, pitch, etc. On treating a gutta percha suspected of containing bitumen with alcohol, much bitumen and other pitches will remain behind untouched mixed with the gutta. Some scheme similar to Henriques' nitro-benzol method for the separation of asphaltum from rubber is evidently required (see pp. 254, 255).—Tr.

[Table

TABLE CXXIV.—COMPARATIVE ELECTRICAL PROPERTIES OF DIFFERENT SAMPLES OF GUTTA PERCHA, INDIARUBBER, RESINS, PARAFFIN WAX, SULPHUR, AND WATER.

Material.	Insulation Resistance. Megohms.		Authority.	Inductive Capacity. Microfarads.			Authority.
	Per Cube Knot.	Per Knot ($\log \frac{D}{d} = 1$).		Air = 1.	Per Cube Knot.	Per Knot ($\log \frac{D}{d} = 1$).	
Gutta percha—							
Cleaned commercial, highest .	139,300	51,050	(1)	4·496	0·0801	0·2184	(1)
,, ,, lowest .	382	140	(1)	2·619	0·0466	0·1272	(1)
Willoughby Smith's special .	955	350	(4)	3·122	0·0556	0·1575	(4)
From leaves—Serrulaz . .	57,980	21,260	(2)	2·950	0·0525	0·1433	(2)
,, ,, . .	120,700	44,260	(3)	3·120	0·0555	0·1515	(3)
,, Obach . .	48,630	17,830	(1)	2·707	0·0482	0·1315	(1)
Balata	2,145	786	(1)	2·724	0·0485	0·1323	(1)
Caoutchouc—							
Pure vulcanised . . .	130,000	47,660	(1)	2·662	0·0474	0·1293	(1)
Mixed vulcanised . . .	81,700	29,950	(1)	3·405	0·0606	0·1654	(1)
Pure unvulcanised. . .	15,440	5,659	(1)	2·505	0·0446	0·1217	(1)
Submarine cable . . .	37,100	13,600	(1)	3·561	0·0634	0·1730	(1)
Overland telegraph cable .	61,770	22,650	(1)	3·405	0·0606	0·1654	(1)
Ebonite	16,540	6,061	(1)	3·160	0·0562	0·1534	(6)
Paraffin wax	34,230	12,550	(1)	2·310	0·0411	0·1122	(6)
Sulphur	21,180	7,764	(5)	3·825	0·0681	0·1858	(6)
Resin—							
Colophony (common rosin) .	21,700	7,952	(1)	2·550	0·0454	0·1230	(6)
Extracted from gutta percha .	14,360	5,264	(1)	3·270	0·0582	0·1587	(1)
Water	...	...	...	75·700	1·3480	3·6770	(7)

(1) Obach. (2) Lord Kelvin. (3) Dr. Hopkinson. (4) Clark and Sabine. (5) Foussereau. (6) Bottzmann. (7) E. B. Rosa.

CHAPTER VIII

GUTTA PERCHA SUBSTITUTES

As with rubber, the excessive prices to which good quality gutta percha has risen have caused the trade to try to replace it, wholly or partially, for special purposes by (*A*) natural products, or (*B*) by more or less analogous compositions (Table CXXV.).

(*A*) *Natural Products.*—A great number of substances have been proposed for replacing gutta percha in cable manufacture, and so obtain cheaper insulators, or insulators more resistant to oxidation, variations of temperature, attacks of insects, and other destructive influences. Several of the substances present in the beginning remarkable dielectric properties, but up to now none of them have shown the almost indefinite unalterability of gutta percha preserved under water. (1) *Paraffin.*—It was at first attempted to use paraffin, but this hydrocarbide is too brittle, and it is only used to protect temporarily from the air the extremity of wires covered with gutta percha. (2) *Ozokerit.*—Then came the turn of Ozokerit. This substance, also called ceresin or mineral wax, is a hydrocarbide which is found naturally intercalated in rather thick layers in the schistose rocks, in the vicinity of petroleum wells, in Galicia, Hungary, Baku, Caspian Sea, the States of Utah and Arizona in North America. The raw material, previously melted to free it from mineral gangue, which amounts to about 15 per cent., is afterwards distilled. It yields on distillation about 15 per cent. of paraffin oil, from which ozokerit solidifies on cooling. The deposit is freed from the excess of oil by centrifugal force and strong pressure. The yield is generally 25 per cent. of the crude material. It is a slightly amber-coloured body, with a very fine granular fracture; it melts between 70° and 80° C., is not saponifiable by alkalies, and is not attacked by sulphuric acid, even when heated to 100° C. (212° F.). Atmospheric agents have no action on the substance. It is at the same time a good dielectric. Combined with small quantities of rubber, it yields softer and more plastic products, which may compete with it as an insulating medium, and in regard to inductive capacity. Henley uses ozokerit in the following manner;—The conductor of plated (polished) copper is first covered with pure rubber, then with a separate grey composition, then with a black composition substance kept secret, and finally pure ozokerit. The core is covered with a layer of felt soaked in ozokerit. The insulation of these cables would appear to rise as high as 5000 megohms per marine mile, after five minutes of electrisation and twenty-hours' immersion in water of 24° C. (75·2° F.). The pitch left in the still from the destructive distillation of mineral wax is also used for cable insulation. Edison gives the resistance of crude ozokerit as 450 million megohms per c/m., whilst that of paraffin is only 110 million megohms; the insulating capacity of the paraffin free residue must be higher, and in fact has proved to be very satisfactory, whilst the power of resisting heat is also considerable.

(*B*) *Mixed Compositions.* (1) *Nigrite.*—By masticating together at the lowest temperature possible, to bring them into a plastic condition, indiarubber and the residue from the distillation of ozokerit, a substance mechanically superior to gutta percha, is obtained, less sensitive to the action of heat than rubber, possessing a superior insulation power to gutta percha, and a notably inferior inductive capacity. Clark and Muirhead have made torpedo cables which appear to have given good results for several years. (2) *White Birch Tar or Gutta Française.*—The so-called *gutta Française* (E. Mourlot Fils, French Patent, No. 13,310; 1879, and additional one of 3rd September 1880), besides improving the gutta by making it more durable in air, was also said to be a specific against the attacks of rats in underground

conduits. But, according to Obach, it renders gutta percha coarse and brittle, and also impairs its electrical properties. We shall only mention, as a matter of reference (3) kerité, (4) Bruce-Warren's rubber, and (5) finally the dielectric employed in the Brook's cables, certainly composed of resins and resinous oils, solid at ordinary temperature. The insulation of these *cables* is extremely high. Several samples tested in England after several months' interval have nevertheless regularly given an insulation of 19,000 megohms per mile. We shall not dwell further on Wray's composition, used especially in hot climates where gutta percha cannot withstand the action of the surrounding atmosphere without softening or even melting. This composition, prepared by a mixture of shellac, caoutchouc, silica, and pulverised alum, to which $\frac{1}{3}$ of its weight of gutta percha has been added, is profoundly and rapidly deteriorated by sea water.

(6) Will the nitrocellulose in appropriate solution as proposed by Nobel yield the results which the inventor claims? Time will tell; and until proof to the contrary we must hold to the opinion that we have expressed at the commencement of this chapter.

(7) *Velvril.*—A mixture of collodion cotton and nitrated castor or linseed oil (W. F. Reid and J. V. Earles, British Patent, No. 21,995; 1895) is one of the recently proposed substitutes. The Velvril paste is moulded like gutta percha, but after hardening it cannot be softened by heat alone. Cord can be made by squirting the paste through a die, and it has been proposed to use it as an insulating envelope in place of gutta percha.

(8) *Chatterton's compound* consists of a mixture of gutta percha, rosin, and Stockholm tar. It is used as a binding material between the copper conductor and the gutta percha envelope, or between the different layers of gutta percha on the core. It is also used for cementing gutta percha to wood. It is prepared thus:—Stockholm tar 1 cwt., rosin 1 cwt., are heated in a steam jacketted pan, then strained and mixed with 3 cwts. of clean shredded gutta percha, the mass being intimately mixed by horizontal stirrers working on a vertical shaft.

TABLE CXXV.—SOREL'S GUTTA PERCHA SUBSTITUTES.

	A	B	C	D
	lb.	lb.	lb.	lb.
Rosin	2	...	...	...
Pitch	2	8	12	...
Rosin oil	8	4	...	...
Coal tar	...	...	...	12
Slaked lime	6	6	6	6
Water	3	...	...	...
China clay	10	...	...	...
Gutta percha	12	16	16	16

In formula A the rosin oil is very evidently meant to act as solvent for the rosin and pitch, the China clay is a mere filler for which other fillers can be substituted. The rosin, rosin oil, and pitch are heated in a pan until dissolved. The lime made into a paste with the water is added, and then the gutta percha; and when the gutta percha is melted, then the China clay is stirred in. Additional water is added and the whole brought to 100° C. 212° F.

Several formulæ for compositions, for insulation purposes, are given in *Mineral Waxes* (Scott, Greenwood, & Son).

THE END

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